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THE

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PROGRESS REPORT ON BLUE-SAC DISEASE

Ken Wolf
Utah Fish and Game Commission
Logan, Utah

AFTER A SEVERE OUTBREAK of the blue-sac disease in a lot of 200,000 lake trout (Cristivomer namaycush) fry, investigations of this condition were started in December 1952.

The objective of the Utah work has been to determine the incidence, cause, and cure or prevention of the disease. To date, more than 250 experiments have been completed. This report covers the results obtained from the earlier of these experiments. A second report will be prepared to cover the bacteriological aspects. Additional information will be released during the course of the study.

HISTORY OF THE DISEASE

The condition among salmonid fry that is known as blue-sac has been recognized for about 50 years. Comparatively little work has been done on the disease, and the last published research appeared 14 years ago. Fiebiger (1904) named the disease Dotterblasenwassersucht (yolk sac dropsy). Von Betegh (1912) used the term Hydrocoele embryonalis.

Some fishery workers believe that there are several kinds of blue-sac, and there are discrepancies among the published descriptions of the disease. Though the final results of this study may indicate otherwise, I believe at present that all the papers compiled by Davis (1946) under the heading "Blue-sac" describe the same condition.

The cause of blue-sac is still uncertain. As Davis pointed out (1946), most of the opinions on the cause of blue-sac are divided into two groups. Some workers ascribe blue-sac to a physical factor; others think that bacteria are responsible.

SYMPTOMS AND COURSE OF THE DISEASE

The most obvious symptom of the disease is the fluid-filled coelom. The fluid is typically a light fluorescent blue and frequently contains red blood cells. The accumulation of fluid is usually visible first at the posterior of the yolk. Maximum development of the sac generally requires several days and ultimately surrounds the yolk. In some instances only a slight accumulation of fluid occurs, and this may persist for as little as several days.

Affected fry are generally lighter in color than normal. This is attributed in part to a general anemic condition due to hemorrhage and in part to a retarded development. In support of the latter, figures 1 and 2 illustrate the smaller body proportions and particularly the smaller chromatophores of affected fry.

Hemorrhages usually appear early in the course of blue-sac. Most often the head is involved, particularly the area around the eyes. Other internal hemorrhages are often found in the dorsal to the thoracic and abdominal regions. Because the hemorrhages usually appear early, I was frequently able to use them to identify and pick off the diseased fish. The presence of blue-sac could generally be verified by close inspection of fish that showed body or eye hemorrhages. Hemorrhages

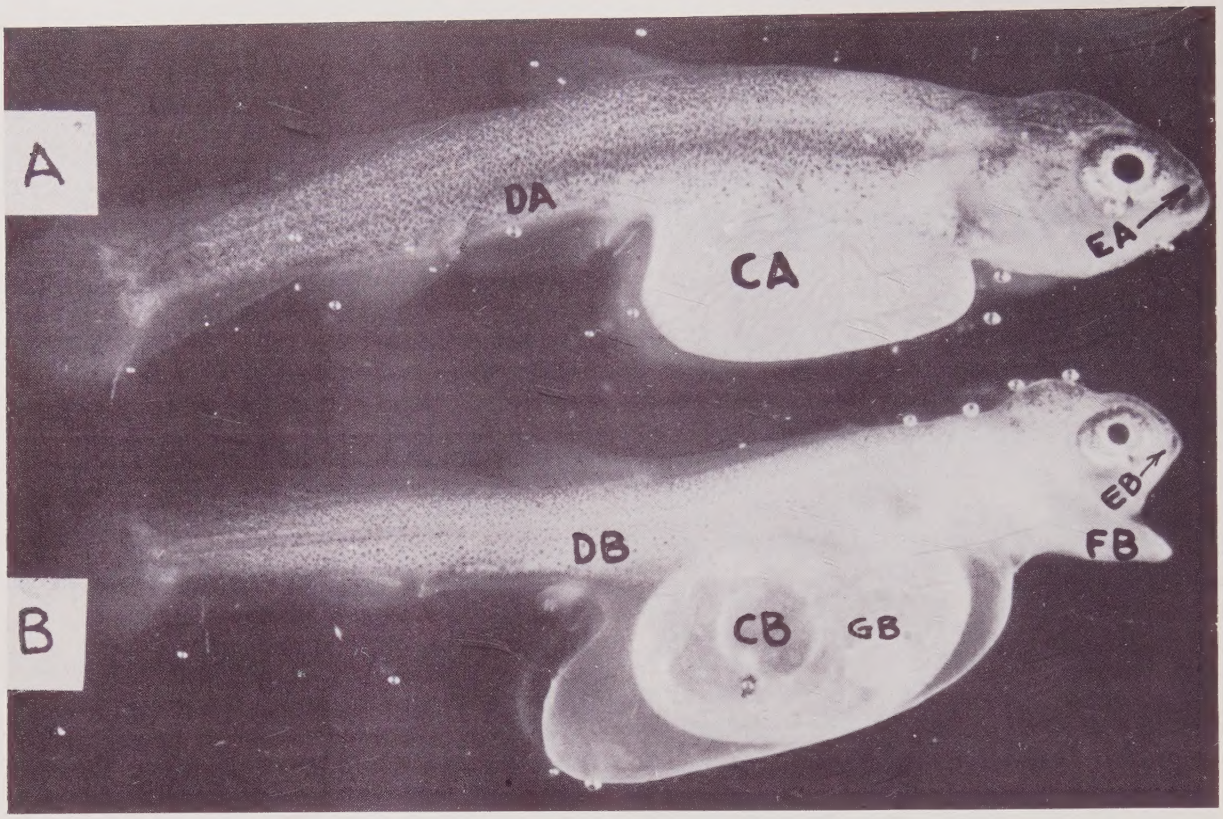

FIGURE 1.--Cutthroat trout fry. A--Normal fish, with spine distorted by anesthesia and heat of illumination. B--Blue-sac fish. CA--Normal yolk blood vessels. CB--Same vessels in diseased fish have broken down and only vestiges remain. DA--Normal chromatophore size and distribution. DB--Chromatophore size and distribution in the diseased fish. EA--Normal snout length. EB--Snout length shorter in diseased fish. FB--Typical gape with the blue-sac condition. GB--White spot on yolk.

are not always present, however, and all fry that show blood-vessel rupture do not exhibit the accumulation of fluid.

The pulse rate of affected fry is about one-half that of normal fry, and this is probably associated with the damage to the circulatory system. As can be seen in the accompanying photographs, the blood vessels that are spread over the yolk have deteriorated in the diseased fry. This is a common occurrence and is believed to be associated with the most severe form of the disease.

Quite recently it has been noted that the hind gut of affected fish is often yellow. This condition is apparently due to a fluid that occupies that portion of the tract.

Guberlet, Sampson, and Brown (1931) reported the presence of a white spot on or within the yolk sac and the culmination of the disease with rupture of the sac and death of the fish. Davis (1946) mentioned white areas on the yolk but stated that rupture of the yolk sac was the exception rather than the rule.

I have found that the white spotting may or may not occur with blue-sac. Because of this, and because white spots have been found associated with the yolk sac when there were no other symptoms of blue-sac, it is probable that white spots represent another condition.

The present study has also shown that the final bursting of the yolk sac is not the usual consequence.

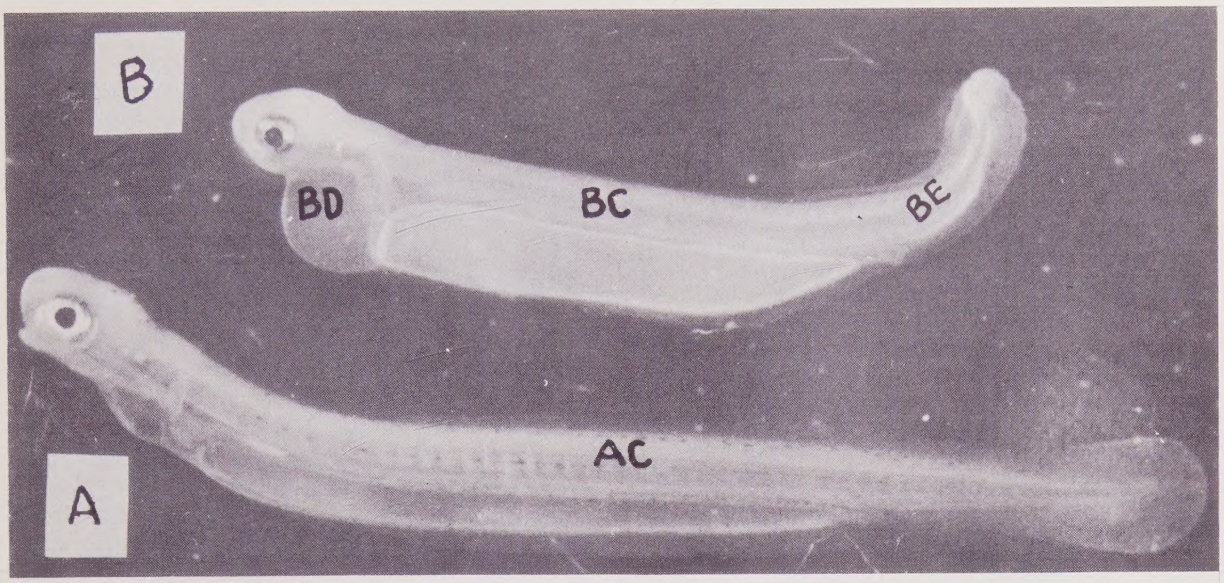

FIGURE 2.--Sucker fry. A--Normal fish, with spine distorted by anesthesia and heat of illumination. B--Fish believed to have blue-sac disease. AC--Normal chromatophore size and distribution. BC--Lack of chromatophores in affected fish. BD--Fluid-filled heart sac of affected fish. BE--Kyphosis of posterior spine in affected fish. (Photos courtesy of the author)

Guberlet, Sampson, and Brown (1931) and von Betegh (1912) implied that blue-sac ultimately resulted in death, and inquiries made in the present study have revealed instances when the loss from blue-sac was complete or nearly so. It is more common, however, for at least part of the affected fry to recover. Dieterich (1939) found that about one-third of the affected fry recovered, and in the present study the percentages of survivals have varied with each lot.

Fry that hatch with blue-sac exhibit greater than normal difficulty in leaving the shell. Whether this is due to a weakened physical condition or to fatigue from moving the bulky shape through the shell is not known, but the former seems likely. This is indicated by the fact that affected fry are not so active as healthy fry and tend to concentrate in the more quiet areas of the tray. When a tray containing both blue-sac fry and normal fry is agitated so as to mix the two, the healthy, active fry will be seen to concentrate along the edges and in the corners, but the sluggish, affected fry will drift to the center. Within a few minutes nearly all the blue-sac fry will be in a relatively small area.

Fry that succumb to blue-sac usually exhibit before death a rigor that simulates paralysis. In the study of survivals, many fry were picked off the trays before actual death because of their appearance. It was subsequently discovered that when these fry were taken from the water and exposed to air, they would respond to probing with a dull instrument. From this it is concluded that their condition is not a true paralysis but a rigor that is induced by the excessive pressure. A similar condition has been observed in severely bloated livestock. The mouth of the affected fry is generally open in a wide gape. At first feeble opercular movement persists, but ultimately this ceases. Death may be precipitated by suffocation.

Time of Occurrence

Davis (1946) stated that blue-sac disease usually appeared within 1 or 2 days after hatching. I have found rather broad

limits to the time when blue-sac appears. In nearly every lot observed in this study some fry hatched with a fully developed case of blue-sac. Most of the fry that develop blue-sac display the usual symptoms within 7 days after hatching in water at 52° F.; in some isolated instances, a few fish may not exhibit the coelomic fluid for nearly 2 weeks.

PHYSICAL FACTORS AS POSSIBLE CAUSES OF BLUE-SAC

Rough Handling of the Eggs

Dieterich (1939) concluded from her work that rough handling would kill the developing embryo rather than cause blue-sac. Von Betegh (1912) reached the same conclusion. I have seen no published work in which rough handling or physical injury has been demonstrated to cause blue-sac, but still the idea is widely held.

The widely accepted methods of shocking eyed eggs to facilitate the pick-off of infertile eggs would seem to contradict the hypothesis of mechanical cause, but experiments were conducted in an effort to determine whether rough handling could induce blue-sac.

Eggs that had eyed and some that had not reached that stage of development were dropped from heights ranging from several inches to about 1 foot. The operation was repeated on successive days. Eggs dropped from only several inches suffered minor losses, but all the eggs that were dropped from a height of nearly a foot were killed. No blue-sac resulted.

Early in the course of this investigation, before rough handling had been (in my opinion) eliminated as a cause of blue-sac, egg-taking operations were started on Swan Creek on the Utah side of Bear Lake. Most of the spawners were cutthroat trout, some were rainbow, and some were hybrids. As a general rule, after fertilization the eggs were allowed to harden and then were washed. A jar partly filled with eggs was completely filled with water in order to eliminate air and prevent turbulence during movement and handling. Surfaced roads spanned the 40 miles to the hatchery, and the eggs were usually on hatching trays within about 2 hours after being stripped. The chances of rough handling were reduced to a minimum, but still blue-sac appeared. Similar results were observed at a commercial hatchery wherein the eggs never left the building in which the spawners had been stripped. In both operations the eggs were hatched on trays and handling was minimized. By contrast, one lot composed of 200,000 cutthroat trout eggs from Yellowstone National Park was received in a standard shipping case. It is assumed that these eggs were subject to far more rough handling than the locally stripped cutthroat eggs, but the Yellowstone eggs hatched with appreciably less blue-sac.

Rough Handling of the Spawners

Some persons have attributed blue-sac to rough handling of the spawners, especially to use of excess pressure in taking the eggs. During this study no fish were handled roughly for the purpose of determining whether this would cause blue-sac, because it soon became evident that blue-sac occurred in spite of precautions for handling and stripping all fish as gently as possible. Hatchery brood stock, particularly in commercial plants, are usually stripped and handled carefully in order to insure survival of the adults and a minimum of broken eggs; nevertheless, blue-sac is known to occur in the fry that hatch from these eggs.

A few naturally deposited eggs which could be identified only as being of the genus Salmo (both rainbow and cutthroat spawners were present) were recovered from one redd in Swan Creek. These eggs were hatched in an aquarium; and among the few that hatched, one fry had blue-sac. This indicates that the disease may occur even in the absence of any handling of the spawners, though some investigators may question the possible physical effects of the removal of the eggs from the gravel in this instance. Rough handling of the eggs has already been discussed.

Drying of the Eggs

In an experiment to determine whether drying could cause blue-sac, eggs were placed on damp cloth in shallow dishes and held "dry" for 4 days at about 54° F. in order to simulate maximum time in transit. The eggs were then placed in hatching trays and hatched. There were no harmful effects; there was no blue-sac.

INCIDENCE

Geographical Distribution

Blue-sac has been reported from both Europe and North America, and it is believed that the disease will eventually be reported from wherever trout or salmon are raised.

In North America blue-sac occurs in Canada and has been reported from most of the areas in the United States where trout are cultured.

Since this study was started, I have not seen a single lot of newly hatched fry that did not have at least some blue-sac disease. Some hatchery operators knew that there had been a few instances of blue-sac in every lot of fry hatched. Other operators said that they had no blue-sac fry; but when trays were carefully examined, particularly in strong sunlight, affected individuals were invariably found. I believe that even though the numbers of affected fish may prove to be small and insignificant in many instances, some blue-sac will be found at one time or another in most hatcheries handling trout or salmon.

Species Affected

The following is a list of fishes reported to have had blue-sac. Unless an author is indicated opposite the species, the information was obtained in the present study.

Cutthroat trout, Salmo clarkii [1/] ---------- Atkinson (1932), others
Rainbow trout, Salmo gairdnerii [1/] ---------- Atkinson (1932), others
Golden trout, Salmo agua-bonita ---------- C. Neider (pers. comm.)
Rainbow X Cutthroat
Brown trout, Salmo trutta ---------- Dieterich (1939), Davis (1946)
Brown X Rainbow ---------- Dieterich (1939)
Lake trout, Cristivomer namaycush ---------- Leach (1924)
E. Brook trout, Salvelinus fontinalis ---------- Davis (1946), others
Dolly Varden trout, Salvelinus malma ---------- C. Neider (pers. comm.)

Dog salmon, Oncorhynchus keta ---------- Guberlet et al. (1931)
Blueback salmon, Oncorhynchus nerka ---------- Guberlet et al. (1931)
Chinook salmon, Oncorhynchus tshawytscha ---------- Guberlet et al. (1931)
Silver salmon, Oncorhynchus kisutch ---------- Guberlet et al. (1931)
Humpback salmon, Oncorhynchus gorbuscha ---------- Guberlet et al. (1931)
Atlantic salmon, Salmo salar ---------- L. Wolf (pers. comm.)

Mountain whitefish, Coregonus sp. [2/]
Bonneville cisco, Coregonus gemnifer [2/]

Utah sucker, Catostomus ardens

1/ "Coastal rainbow and cutthroat trout--the 'steelhead trout'--are both subject to blue-sac."--G. C. Webb (personal communication).

2/ Naturally deposited eggs were recovered from shallow waters of Bear Lake. The genus is certain; the species gemnifer is probably correct.

As may be seen in the foregoing, most of the salmonids are subject to blue-sac. Those not listed are being investigated and will, in all probability, be included in the future.

The taxonomic position of the genus Coregonus is close to the positions of the salmon and trout (Salmonidae), and it is not unexpected that the whitefish are susceptible to blue-sac.

The sucker is not related to the salmonids, and the appearance of blue-sac was not expected even though the eggs were hatched to see whether the fry were susceptible. It should be pointed out that the eggs were incubated on trays and transferred to a large jar as soon as the first individuals hatched. The slim, eel-like form of the fry permitted easy escape through normal screen mesh. Figure 2 shows only the anterior prominence of heart-sac dropsy, the blue-sac condition, and the accompanying deformity. Lateral blisters were also present but, because they were transparent, did not photograph against the body of the fish.

If the sucker eggs had not been transferred to a jar prior to the time of hatching, the fry would have been lost and the determination would not have been made. Subsequent lots of sucker eggs were incubated in a Chase jar; but, probably because of faulty technique, few, if any, remained in the jar to hatch. Normal hatching in Chase jars is in such decided contrast to the comparatively close attention given the large salmonid eggs that it is easy to understand why blue-sac has not been reported among the "warm water" fishes.

Susceptibility

Though the species of trout available for experimentation here are few, the results of the work indicate that there is a differential susceptibility among species and among individuals within a species. I have worked with lake trout, brown trout, cutthroat trout, rainbow trout, and hybrids of the last-named two. Of these fish, the lake trout have been the most seriously affected. Jack Bailey, hatchery biologist in the State of Montana, has written about the loss of 100 percent in brown trout and nearly 100 percent in eastern brook trout (personal communication). From the work that has been published, it seems that eastern brook trout are very susceptible, but again there are exceptions. A hatchery superintendent told me that the only lot of fry in his experience that passed the sac stage without blue-sac was a shipment of eastern brook trout. Rainbow trout, as a rule, have been found to be more resistant; and this finding agrees with what others have observed.

Occurrence Under Natural Conditions

That blue-sac occurs in the fry that hatch from eggs stripped from fish of wild populations has been reported in several papers. This is particularly true of the salmon, and Dieterich (1939) has given evidence for trout. This is deemed indicative (though admittedly not conclusive) evidence that the disease occurs in fish hatched in natural environments. My own attempts to recover newly hatched fry from redds has so far met with failure. High run-offs and suckers that spawned later have covered the marked redds, so that attempts to recover fry have been unsuccessful.

As was reported earlier, blue-sac developed in the fry of several species whose eggs were collected from natural spawning sites and hatched artificially. The disease also occurred in the fry that were hatched from eggs which had been stripped from a wild female and incubated in the gravel of the spawning stream. In view of this, it is my opinion that blue-sac will eventually be demonstrated in natural environments. Further investigations are planned for this fall and winter.

Blue-Sac and Anomalies

Dieterich (1939) mentioned the concurrence of blue-sac and certain deformities, particularly those deformities involving the spine and/or portions of the head. Dieterich's findings with regard to eye defects and jaw deformities have been corroborated in this study. Surber (1935)

mentioned blue-sac and deformities noted after an excess of dissolved gas in the hatchery water. Mr. Surber was contacted to determine whether the blue-sac and the deformities occurred in the same individuals, but he no longer had the original data (personal communication).

Early in this study it became evident that there was a much higher incidence of blue-sac among anomalies than among the normal fry of the same brood. In one lot of rainbow eggs, the incidence of blue-sac among the normal fry was 1.47 percent. All anomalies were isolated, and the average incidence of blue-sac for two separate groups was 26.1 percent. Although in later lots of fry the proportions varied, the incidence of blue-sac among anomalies was consistently higher.

Severe scoliotic deformities that produced a corkscrew of the body were very frequently affected with blue-sac disease. Lordotic deformities -- generally called "pinwheels" -- were similarly affected.

Fry exhibiting posterior scoliosis were similarly involved. Because, however, the large sac in blue-sac may distort the body and simulate mild scoliosis, a clear separation of the two possible scoliotic deformities could not always be made.

Rucker, Whipple, and Parvin (1953) gave evidence of a virus infection producing spinal deformities. Both in blue-sac and in the desease cited by Rucker (Rucker et al. 1953), not all the diseased fish exhibit the deformity. The fact that the deformities illustrated by Rucker and his co-workers are caused by an organism and are similar to deformities that occur concurrently with blue-sac is interesting, and preparations have been made to explore this field further.

Among the deformities of fry that do not show the blue-sac condition, some are undoubtedly the result of injury after the hatching. Other deformities, such as the short-spined "chubbies," are hereditary in nature. This is true of conjoined twinning. I am of the opinion that conjoined twinning is the result of a genetic factor and I estimate its occurrence at the rate of about 3 per 10,000 hatched fry. The ratio of conjoined twins to normal fry before hatching is probably slightly different. The acetic acid and salt solution given by Dieterich (1939) has been used in this study to clarify dead eggs and has given excellent results. After clarification, twinning is easily recognized within the dead egg.

Because of the blue-sac investigations, the eggs of most females stripped at Swan Creek were hatched on separate trays. As is the general practice, males were held over and used several times. The fry that hatched from eggs of one female stripped during the middle of the season had more than 20 percent conjoined twins. Development of one of the twins ranged from partial to complete; relation of the joining was lateral, sublateral, and vertical on the ventral sides. The twins showed slightly greater percentages of blue-sac disease than the normal fry but far less than the incidence among the other anomalies.

Several females which were stripped during this same period also produced greater than normal numbers of conjoined twins, and it has been concluded that one of the males was the carrier of the responsible gene or genes.

It is known that some deformities are hereditary expressions. Because other deformities exhibit a greater percentage of blue-sac than the normal fry of the same lot, it is concluded that the two are in some way related.

ASSOCIATED PHENOMENA

This study has revealed that the more severe outbreaks of blue-sac are generally preceded by higher than normal egg losses. The eggs in these lots are generally fertile and characteristically burst before hatching time. Small quantities of yolk are usually extruded through the ruptured shell, and the head is often exposed.

The regularity with which the last eggs that hatch have greater numbers of fry emerge with blue-sac disease is thought significant. The accumulation of fluid is a relatively slow process; several days are generally required to achieve maximum swelling. Though the term "incubation" is

used with some misgivings, it would seem reasonable to conclude that the time required in hatching is not sufficient for incubation of this disease from a postulated exposure when the shell is first breached. On several occasions I isolated mountain whitefish (Coregonus) eggs that appeared blue. It was possible to do this because these eggs lacked pigment and had greater transparency than trout eggs. The eggs were segregated several days before hatching. Though all the segregated eggs did not hatch blue-sac fry, there was always a much higher percentage of the condition than in the eggs that were not blue. In view of this evidence, it must be concluded that the disease started or could start during the prehatching development. Schereschewsky (1935) considered that the start of the condition took place sometime before hatching.

COMMENTS

It is realized that there are many gaps in this report. Much work has been done in the bacteriology of blue-sac, and it is planned to report on that phase next.

At this time the question of contagion is still unanswered. Certainly there has been no positive evidence of transmission from diseased fry to healthy fry under normal hatchery conditions. Experiments with exposures to, and inoculations of, fluid from diseased fish and experiments with cultures of bacteria present in the fluid have not given consistent results or clear-cut proof of a bacterial agent. Many data are being processed and analyzed for possible significance.

Various percentages of fry recover from blue-sac, but it is doubtful whether the diseased fry should be kept in order to salvage the recoveries.

Whether blue-sac is an infectious disease remains to be determined. Disposition of the diseased fry should be governed by several factors. Recoveries from the disease are variable, and generally they form a low percentage. In the interest of sanitation and to check the growth of Saprolegnia on the dead fry, blue-sac fish were picked off and destroyed.

Chemical treatment of diseased fry has been ineffective. Because of the prevalence of the irreversible breakdown in the circulatory system, it is believed that for all practical purposes treatment will consist of prophylaxis rather than therapy.

Other Investigations

Of necessity, the nature of this work is such that several phases cannot be exhaustively investigated here. In the interest of more speedily securing complete data and a solution to the blue-sac problem, assistance from interested persons is requested and will be greatly appreciated. Information regarding the incidence of blue-sac among additional species of fish is needed, as are reports of the disease from additional areas where trout are cultured. It is hoped that someone will have or has had the opportunity to recover fry from natural redds and to determine whether blue-sac occurs naturally.

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CHAR SPAWNING IN OBSERVATION TANK IN SWEDISH LABORATORY

As the demands of power companies have caused many of the lakes in northern Sweden to be subject to surface fluctuations during the year, a laboratory has been established in Drottningholm for research on problems of fish life in these regulated lakes.

Dr. Norman O. Levardsen of DeKalb, Illinois, who has recently visited a number of the fishery research stations in northern Europe, reports that at the Sotvattenslaboratoriet Dr. Eric Fabricius has been studying the behavior of the char (Salvelinus alpinus) in an observation tank 30 feet long, 3 feet wide, and 2 feet high. Only since the installation of a cooling system during the summer of 1953 has it been possible to maintain the water in the tank at any desired temperature. During the fall of that year, however, Dr. Fabricius apparently had no trouble in getting the char to spawn. Moreover, when Dr. Fabricius' colleague undertook to record the activity on kodachrome, the fish soon became accustomed to the necessary bright lights and resumed their spawning.

"The long tank is divided into seven sections," writes Dr. Levardsen. "Each section has a different kind of bottom material, which ranges from fine sand, through various-sized gravels, to large stones. Since the fish have free access to every type for spawning, the one chosen may be assumed to be the most desired. Gravel, slightly smaller than walnut-size, was the material chosen above all others.

"In another tank where the desired gravel was covered by a pane of glass, the female endeavored to dig a nest with her tail on the glass plate. Sand in the same tank was not utilized; but when suitable gravel was introduced, at one side of the glass plate, spawning commenced immediately."

POLLUTION: ITS NATURE AND EVALUATION

Bertil G. Anderson
West Virginia University
Charleston, West Virginia

WATER is our most important natural resource. All of us should be concerned about it, as all of us use more water than any other substance. Water, as you know, makes up two-thirds of the content of our bodies. Some organisms, such as the jellyfishes, are more than 95 percent water. Some forms of living matter have very low percentages of water--but only when they are in a dormant state. Young and growing plants and animals contain more water and are more active than mature organisms. As far as we know, life depends on the availability of water.

Water is used by practically all industries, and many industries use more water than any other substance. I believe that it is perfectly safe to say that industrial progress depends on the availability of water.

Water has a unique set of properties which are duplicated by no other substance; so we can say that there is no known substitute for water. We should even go farther and say that there is no substitute for suitable water.

Many of us have paid very little attention to our water resources because of their apparently limitless quantities. We have oceans of it. Nevertheless, as our population has increased and tended to concentrate in cities, and as industry has expanded, more and more of us have become conscious of the fact that our water resources are not limitless, that enough suitable water is not available for all purposes. In some areas we have reached the point where it can be said, as the Ancient Mariner did, "Water, water everywhere and not a drop to drink." We can find many such areas without looking to the oceans.

What has happened to our apparently limitless water resources? We have found that these resources are not limitless. Moreover, we have used much of what we have in ways that render it unfit for further use without extensive reprocessing. In other words, we have polluted it. The pollution bill passed at the last session of the Legislature of West Virginia states that "'Pollution' shall mean the discharge or deposit, directly or indirectly, of sewage, industrial wastes or other substances, in such condition, manner or quantity as may contaminate or alter the physical, chemical or biological properties of any of the waters of the state to such extent as to render such waters directly or indirectly detrimental to the public health or unreasonably and adversely affect such waters for present or future domestic, commercial, industrial, agricultural, recreational or other legitimate uses."

We trust that for legal purposes this definition is satisfactory. But, you ask, when are waters detrimental to the public health? When are waters unreasonably and adversely affected for domestic, commercial, industrial, agricultural, recreational, and other legitimate uses? Actually the answers to these questions

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are as limitless as our imaginations. They are as limitless as the qualities of natural waters multiplied by the number of processes in which water is used, multiplied again by the number of possible processes in which it might be used. The qualities of natural waters vary considerably, depending on the amount of rainfall and the land over and through which the water flows. Consider the variations in the soil to which the water is exposed, whether the terrain is open or wooded, whether it is rocky or flat, whether the geological strata that it cuts are limestone, sandstone, or shale--and you have a picture of the possible variations of the substances present in the water to modify its qualities. As this water is used by man for his own personal consumption and for his hundreds of industries, the qualities of the water are changed and we have new problems. But man wants to use this water again and again, and so the possible changes in water quality multiply in an endless fashion. No one person has all the answers; no one person can study all these problems in detail.

Personally I have been interested in determining the tolerance limits of aquatic animals for various substances that are found in industrial wastes. I should like to take this opportunity to explain my approach in studying this subject.

First, let us have a look at water in relation to the requirements of aquatic animals. I doubt whether anyone has ever had any absolutely pure water; and if it were available, I am certain that it would not sustain life. Life needs more than water alone for maintenance. Oxygen is required in most cases. Carbon is necessary in some form or other. Minerals of many kinds are essential. Not only are certain elements necessary, but they must be in proper compound form. In general, natural waters contain these substances.

Let us follow water from the time it forms as a raindrop until it reaches the oceans. As soon as a raindrop forms, it absorbs oxygen, nitrogen, carbon dioxide, and other gases from the atmosphere. As it falls, it collects particles of various kinds, dusts from far-off deserts, ashes from volcanoes, radioactive materials from atomic explosions, and particles from more neighborly sources. As it approaches the earth, our raindrop is far from being pure water. On reaching the earth, the raindrop comes in contact with vegetation, soil, and rock; it dissolves as much as possible and reacts with them. In addition, many substances become suspended in it. Our raindrop is still farther from being pure water. Should we regard our raindrop as polluted? I think not. It is the kind of water that most aquatic animals thrive in. It is the kind of water in which we feel that living matter originated. Water that is chemically pure does not contain the substances that living matter is made of; so such water will not support life. The impurities that come from the air and the earth, together with water, make life possible.

What, then, is polluted water? Natural waters contain almost everything under the sun, and living matter abounds in it. Few of us can think of anything to add that is not already present in natural waters. Polluted waters differ from natural waters in the relative quantities of the impurities present. A certain range of concentrations of a particular substance may be regarded as optimum for most organisms. Other concentration ranges may be more suitable for other but fewer organisms. As we move farther from the range that is optimum for most organisms, fewer and fewer organisms will survive. In other words, a certain amount of a substance is beneficial, but both lesser and greater amounts are lethal.

Let us take some examples. Fluorides are essential in certain quantities for the development of sound teeth. If enough fluoride is not available, the teeth do not develop properly and will be subject to excessive caries. With a little too much fluoride, mottled enamel results but the teeth may otherwise be sound. A somewhat greater amount of fluoride causes fluorosis, a condition in which the teeth practically disintegrate. We need the optimum amount of fluoride for proper dental development.

The optimum pH range for most fishes is from 6 to 9. When the pH of a water goes below or above these values, many of the activities of most fish are reduced. A pH changed to 2 or 12 and maintained there for a few hours would be enough to kill most, if not all, of the fish.

Our problem is even more complex because optimum concentration ranges are not constant. The optimum concentration of a substance varies with the concentration of other substances in the water. Natural waters are extremely variable in composition. Large lakes are relatively constant, but this applies only to such lakes as our Great Lakes. Small lakes are not so variable as streams, but even these lakes vary considerably. The composition of streams varies from day to day and from season to season. We know relatively little about optimum concentrations for aquatic animals. This is not surprising, as only a handful of investigators have taken an active interest in this field.

Organisms will probably make use of anything that we may add to streams, provided that we do not add so much that the optimum is exceeded under a particular set of conditions. It is only when we exceed the optimum concentrations that organisms are adversely affected, and then the water is polluted. A substance becomes a pollutant only when it is present in excessive concentrations.

When a stream is polluted, the population of the stream changes. The changes which take place vary with the pollutants. If, as happened in the Shenandoah River, too much zinc was permitted to enter the river, most of the organisms which we regard as characteristic of streams disappeared from 60 miles of the river. Fish, snails, and insect larvae were killed, so that the stream was almost sterile.

When acid mine waste enters a stream, the waters may become so acid that very few organisms survive. Deckers Creek near Morgantown has but few organisms that are typical of an unpolluted stream. The Monongahela contains many flagellates and diatoms which seem to thrive under such conditions, but it supports relatively few other organisms.

When a considerable amount of domestic sewage is permitted to enter streams, the population changes largely because bacteria reproduce rapidly under such conditions and reduce the oxygen level of the waters to a degree that many fish and other organisms cannot survive. Those organisms which can tolerate low oxygen levels will thrive, as competing organisms and the predators will disappear from the scene.

In general, the populations of polluted waters include fewer species than the populations of unpolluted waters. The greater the degree of pollution, the fewer the species. To put it still another way: The number of species is, in general, inversely proportional to the degree of pollution.

I have dealt only with a portion of the general problem of pollution. Most of us think of pollution in terms of the dispersal of water-borne disease-producing organisms. Another phase of pollution is concerned with alterations which render water unfit for industrial purposes. Some manufacturing processes are much more touchy with respect to the composition of water than are living organisms. Water having a hardness of more than 50 p.p.m. was found to cause trouble in a synthetic rubber plant in this State. The steel industry prefers waters having--among other specific characteristics--a pH of 6.8 to 7.0, a hardness of less than 50 p.p.m., and chlorides amounting to less than 175 p.p.m. Industry, like living matter, demands water of certain specifications. Excessive quantities of dissolved and suspended materials pollute water for industrial uses as well as for aquatic organisms.

Up to this point I have attempted to develop a general concept of the nature of pollution. I should like now to consider the evaluation of pollution. If we proceed on the assumption that polluted waters contain excessive amounts of various substances, our problem is one of determining the amount in excess of the optimum for aquatic organisms and for industry.

Some industries know their needs with respect to water quality, as I have pointed out. The needs of aquatic organisms have been established for some substances but not for very many. The determination of the optimum concentration for each potential pollutant is a task that will not be accomplished for decades to come. The time and energy of a large number of investigators will be required. To appreciate the magnitude of the task, consider the work that has gone into the project of establishing the daily requirements of human beings for thiamin, multiply this effort by as many substances as there are potential pollutants, then multiply that product by the number of aquatic organisms that we may consider essential--and you have the answer. Experience and the fact that organisms are not so different from each other should make the job become easier.

A good start on this job has been made. Less than a year ago the State Water Pollution Control Board of California published a volume entitled "Water Control Criteria." In this work pollution is discussed from a wide variety of standpoints. About half of this 500-page report is devoted to a review of the literature on the effects of potential pollutants on domestic water supplies, industrial water supplies, irrigation water, stock and wildlife watering, fish and other aquatic life, and like topics.

As I have pointed out, we know relatively little about the optimum concentrations of potential pollutants and to accumulate any substantial amount of this type of information will take long-term experiments. We do have a considerable body of data on the concentrations in which potential pollutants are acutely toxic; i.e., concentrations that will kill or disable in a week or less. Obviously, the optimum concentrations must fall below the toxic concentrations. Though a knowledge of concentrations which are acutely toxic leaves much to be desired, such data are of considerable value in pollution-abatement programs. Certainly pollutants should be kept below those concentrations which are known to be acutely toxic.

Many years ago when I was a graduate student, I was introduced to an animal known as Daphnia magna. I worked with this animal on various projects which had nothing to do with pollution. At that time, however, the possibility of using it for biological-assay purposes seemed very good and I decided that, should the opportunity arise, I would work on that aspect. I was not the only one who had that idea. Several investigators have used Daphnia magna for bioassay purposes.

The use of Daphnia magna is advantageous in many respects. Daphnids are small, approaching a maximum size of 6 mm.; so a great many can be reared in a small space. They have a relatively short life span, reaching a maximum of about 2 months when reared at 25° C. Daphnids are easy to culture. They can be grown individually in small bottles or in mass culture in large aquaria. They mature early, giving birth to young within their first week of life. After the first brood, the daphnids give birth to new broods every 2 or 3 days throughout the remainder of their lives. An average of 20 or more young may be produced in each brood. Each female that lives to a ripe old age can bear 400 or more offspring. Again, all the young from any one female are genetically like the mother if produced parthenogenetically, and reproduction can be limited to parthenogenesis if the proper conditions are maintained. Individuals in any stage of their life span can be obtained at all seasons. Further, daphnids are representative of a class of animals serving as food for many fish, especially while the fish are young. Fish do not remain long in waters where their food supply has been destroyed, even though the fish may not be affected directly.

The procedure which has worked well for me when using Daphnia in the determination of the toxicity of wastes is to rear a hundred or so females individually in small bottles. Once a day the young are segregated. By using these young as experimental animals, age is kept under close control, a condition which is important because as animals grow older they are less susceptible to toxic substances.

These young daphnids are introduced into a series of concentrations of the substances in question. Observations are made at definite intervals over a period of 100 hours, and the number of animals that remain alive in each concentration is determined in each observation. This is very easy because live Daphnia are on the move continuously. In this way the concentrations which are toxic and those concentrations which are apparently nontoxic can be ascertained. This is the same general method that is used with fish and other animals.

I have determined the apparent threshold concentrations of toxicity for more than a hundred different substances, using Lake Erie water as the diluent. My results do not always agree with those other workers have found when using other animals. Sometimes the differences have been great, but for the most part the differences have been relatively small. In general, Daphnia appear somewhat more susceptible to toxic substances than fish.

These experiments, like others on acute toxicity, are test-tube experiments. We need field investigations where the concentrations of pollutants are under control at levels below those that are known to be toxic under laboratory conditions. Only after such studies will the value of our laboratory tests be known. On the whole, industry seems willing to cooperate. In the past, the coal industry has been exempted from responsibility for polluting our water courses. Our newly revised law exempts no polluter. At some time in the future--I trust in the not too distant future--West Virginia will have streams that can be used by anyone for almost any purpose.

RESEARCH ON "RED TIDE" IN FLORIDA

At intervals during the last century there have been a number of outbreaks of "red tide" along the central west coast of Florida. Since the major outbreak of 1946-47, however, high concentrations of the microorganism called Gymnodinium brevis have been abnormally frequent. To prevent further mass mortalities of fish and aquatic life in consequence of these "blooms," biologists of the U. S. Fish and Wildlife Service are seeking to determine what factors contribute to such rapid increases in number of the organism and what control or preventive measures may be undertaken.

Research has already indicated that the effluents of such waters as the Caloosahatchee River may be important agents in the development of conditions favorable to outbreaks of Gymnodinium brevis in this part of the Gulf of Mexico. The problem in these coastal waters is further complicated, however, by the presence of decaying fish bodies--killed by the organism--which are believed to release nutrients that nourish the organism and serve to intensify the plague. Also, tank studies have already indicated that a mass growth of dinoflagellates--as of any other organism--requires high light intensity, vitamin B_{12}, and sulfides.

Gymnodinium brevis has recently been cultured in the laboratory under controlled chemical and physical conditions. One culture has been under observation for 7 months, and specimens have been taken from this in order that new cultures may be started for study under various other conditions. The culturing of this dinoflagellate under controlled conditions may be expected to furnish information regarding the basic requirements for its survival and rapid reproduction.

Field studies designed to detect outbreaks of "red tide" are being made from a new laboratory at Ft. Myers, Florida. This will be the base of operations, too, of a new research vessel obtained for studies to determine the prevailing ocean currents along Florida's southwest coast and the tidal exchange of coastal waters with nearby land drainage systems.

EFFECT OF STARVATION, WATER TEMPERATURE, AND SODIUM AMYTAL ON THE METABOLIC RATE OF BROOK TROUT

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and
Donald R. Brockway, New York State Conservation Department, Cortland, New York

FOR SEVERAL YEARS it has been thought that the metabolic products of the trout are the limiting factors in the establishment of the carrying capacities of holding equipment. Previous experiments made at the Cortland Laboratory (Brockway 1950, Phillips et al. 1951) have shown that the removal of products of metabolism from the water is advantageous to the trout physiology. However, in the use of fish distribution units, it would be more practical to prevent the formation of these products of metabolism than to remove them after their formation.

Calhoun [1/] reported that the use of sodium amytal, a hypnotic drug, at the rate of 0.5 grain per gallon of water increased the carrying capacity of shipping tanks. He postulated that the reduced rate of metabolism prevented the accumulation of toxic products and hence increased the load potential of the equipment.

In addition to the use of drugs, there were other means of reducing the metabolic rate which merited consideration. Of these other means, starvation and cold water were the simplest to apply. With this in mind, the writers designed this series of experiments in which the effects of cold water, starvation, and the drug sodium amytal on brook trout were measured in terms of metabolism as estimated by the accumulation of ammonia and the utilization of oxygen by trout.

Trout were held in stainless steel aquaria (14 by 6 by 8 inches) which had been painted inside with black asphaltum paint. Sufficient aeration was secured by means of a perforated rubber hose which was run around the bottom of the aquarium. The use of this device prevented the fish from grouping around a single air outlet, as would have occurred if an aeration block had been used.

At intervals during a 12-hour period the water in the aquaria was analyzed to determine the ammonia present (direct nesslerization) and the oxygen remaining (Winkler).

Two series of experiments were run. In the first series the fish were starved for a 15-hour period (overnight), and in the second series the starvation period was increased by an additional 48 hours (total, 63 hours). This second period of starvation was chosen because earlier work had shown that it took approximately 2 days (after the feeding) for food to leave the digestive tract of trout of the size used in these experiments (16 to 30 grams in weight). The second series of experiments was therefore expected to measure the metabolic products of nonfeeding animals and to eliminate the interactions of absorption, digestion, and preliminary assimilation of foods in the body.

In each of these series the trout were held at two water temperatures, one being 51° F. (which was obtained in a constant-temperature room) and the other 34° F.

1/ **Calhoun, Alex, 1953: Hypnotic drugs as an aid in fish transportation. California Department of Fish and Game. Mimeographed.**

(which was obtained by placing the aquaria in tubs of cracked ice held in the constant-temperature room). The water temperature of 51° F. was used in all experiments except where water temperature itself was the variable.

In each of these series there were also experiments in which sodium amytal was added at the rate of 0.5 grain per gallon of water.

Early in the work, the investigators encountered difficulties in trying to obtain duplicate results. A number of preliminary experiments showed, however, that these difficulties could be overcome if a series of conditions was strictly maintained. Throughout this paper, those experiments in which the conditions set forth here were followed are called the control. The conditions were as follows:

1. The amount of air entering the aquaria was set at the start of the experiments and was not adjusted again throughout the two series of tests.
2. The trout were fed at 4 p.m. and were used either at the following 7 a.m. before feeding (15 hours' starvation) or at 7 a.m. 2 days later (63 hours' starvation). A variation of as little as 1 hour from the 4 p.m. feeding time affected the results.
3. The aquaria were stocked at the rate of 3,400 grams of fish per 7 liters of water. Under standard conditions this gave a mortality large enough to show significant differences and, at the same time, prevented a total loss of the trout.
4. All experiments were run for a 12-hour period, after which the trout were placed in running water. The loss of fish was recorded 24 hours after the fish had been placed in running water.

Each experiment was run in triplicate. The results of the experiments are shown in table 1.

Trout Starved for 15 Hours

Control. -- The ammonia accumulated rapidly throughout the 12-hour period and at the end was in excess of 25 p.p.m., an amount which was beyond the range of our method of analysis. The fish were in obvious distress, and the loss averaged eight trout per aquarium after the fish had been in fresh water 24 hours. At the end of the test period, the oxygen that remained in the water was at a level of 3.2 p.p.m. It is interesting to note the rapid drop in oxygen during the first hour (from 10.4 to 5.8 p.p.m.). This drop probably can be explained by the increased activity of the fish as a consequence of the handling and placement in the closed system.

Effect of 34° F. water temperature. -- The ammonia accumulated slowly in the water and by the end of 12 hours was at a level of 8.1 p.p.m., or about one-third of the accumulation in the control. The initial drop in oxygen was much less (as compared to that of the control) and was probably the result of the greatly reduced initial activity due to the effects of the cold water. At the end of the experiment, the oxygen was at a level of 5.6 p.p.m., considerably higher than that of the control. The trout were in excellent condition, and no losses were recorded. No effort to temper the fish was made; they were removed directly from water at a temperature of 47° F. to water that had a temperature of 34° F., and 12 hours later they were returned directly to the warmer water. Although the fish were in obvious distress for about 5 hours after being placed in the warmer water again, no losses were observed even after a period of 7 days.

Effect of sodium amytal. -- The use of this drug had no apparent effect on the accumulation of ammonia. At the end of 12 hours, the level of ammonia was in excess of 25 p.p.m. The oxygen content of the water dropped to the same level that was recorded for the control, and there was no difference at any of the time intervals (table 1).

TABLE 1.--The effect of starvation, water temperature, and sodium amytal on the metabolic rate of brook trout, as measured by the accumulation of ammonia and the oxygen remaining in the water

Treatment	Accumulation of ammonia, p.p.m., in number of hours						Oxygen remaining in water, p.p.m., in number of hours						Mortality at end of 24 hours
	1	2	4	6	8	12	1	2	4	6	8	12	
Trout starved for 15 hours													
Control[1/]	3.3	5.0	7.9	9.7	18.5	25.0	5.8	5.5	5.1	5.0	4.3	3.2	8
Held in water at temperature of 34° F.	1.8	2.7	3.9	4.5	5.0	8.1	7.3	8.3	7.6	6.8	6.4	5.6	0
Sodium amytal at rate of 0.5 grain per gallon	3.8	4.9	8.4	8.7	20.1	25.0	5.9	5.3	5.1	4.8	3.5	3.1	8
Trout starved for 63 hours													
Control[1/]	1.9	2.8	4.3	5.5	7.3	13.5	5.8	5.8	5.8	5.8	5.9	5.2	0
Held in water at temperature of 34° F.	1.1	1.6	2.6	3.1	3.9	6.9	9.6	9.7	7.9	8.0	7.9	7.5	0
Sodium amytal at rate of 0.5 grain per gallon	1.6	2.6	4.1	4.9	5.2	7.6	6.0	5.9	5.8	5.8	5.9	5.3	0

[1/] Control held at 51° F. All aquaria stocked at rate of 3,400 grams per 7 liters of water. Aeration remained constant for all experiments. Oxygen in water at start was 10.4 p.p.m.

Trout Starved for 63 Hours

Control. -- This increased period of starvation reduced the accumulation of ammonia by about one-half (as compared to the control for the previous series). There was no loss among the trout and the fish were in fair condition at the end of 12 hours. Although the identical initial drop in oxygen was noted, the rate of utilization (as measured by oxygen that remained in the water) was decreased during the experiment so that at the end of 12 hours the level in the water was 5.2 p.p.m., or considerably higher than the level in the control of the first series.

Effect of 34° F. water temperature. -- The accumulation of ammonia was greatly reduced and at the end of 12 hours was only 6.9 p.p.m. No losses of fish were recorded, and at the end of the experiment the fish were settled quietly on the bottoms of the aquaria. The initial drop in oxygen (first hour interval) was much less than that of the other experiments (from 10.4 to 9.6 p.p.m.), and at the end of the test period oxygen was still at the level of 7.5 p.p.m.

Effect of sodium amytal. --The amount of ammonia accumulated during the entire period was greatly reduced (as compared to the accumulations in the controls for both the first and the second series of experiments). In fact, the accumulation of ammonia was only slightly higher than the value found for the cold-water group of this series. However, as shown in table 1, the accumulation of ammonia paralleled that in the control during the first 4 hours, and thereafter ammonia accumulated at a decreasing rate. This indicates a delayed action of the sodium amytal, which is probably a factor of absorption. The delayed action probably represents the time necessary for the drug to reach a critical level in the blood of the trout, a level at which the hypnotic effect takes place. The fact that such a delayed action was not observed during the use of the drug in the first series, indicates that the effect of the sodium amytal can be correlated with starvation. In recently fed trout, the rate of metabolism is apparently such that this drug cannot slow it down sufficiently to reduce the formation of metabolic products during the 12-hour experimental period. Compared to the results in the control aquaria (table 1), the drug did not affect the utilization of oxygen (measured by the oxygen remaining in the water) during the experiment. The initial drop in oxygen (first hour) was approximately the same as the initial drop in the control aquaria and much greater than the drop seen when the fish were put in cold water. The inability of the drug to slow down the fish immediately is further revealed by this fact.

General

Both cold water and the 63-hour period of starvation were effective in reducing the metabolic rate as measured by the accumulation of ammonia and the amount of oxygen remaining in the water. Of these two variables, cold water was the more effective. In fact, when the trout were starved for only 15 hours and then subjected to cold water (first series), the results were superior to those in the control of the second series (63 hours' starvation). The combination of cold water and 63 hours of starvation resulted in a still further reduction of the metabolic rate.

The drug sodium amytal was effective when it was used in combination with the longer period of starvation but had no effect when used with the shorter starvation period (15 hours). The action of the drug was delayed between 4 and 6 hours.

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COMMENT

State of Michigan
WATER RESOURCES COMMISSION
P. O. Box 87
Lansing 1, Michigan

November 24, 1953

Department of the Interior
Fish and Wildlife Service
Washington 25, D. C.

Attention:
Editors, The Progressive Fish-Culturist

Dear Sirs:

In the July issue of The Progressive Fish-Culturist, Dr. Levardsen in his "Experiments With Nigrosine Dye in Aquatic Plant Control" (vol. 15, no. 3, pp. 109-113) reports such discouraging results with the dye that I feel some comments are in order to prevent the possibility of an early burial of something which might in the future prove useful to the pond culturist with coarse-weed problems.

Dr. Levardsen's treatment of Loon Lake came late in the season, July 17, 1948, apparently after the lake was choked with weeds. Our most encouraging results--and they were with one of the worst of our pond weeds, Anacharis canadensis--came in the first treated of several ponds. (See The Progressive Fish-Culturist, vol. 12, no. 3, pp. 135-140.) The most successfully treated pond, H-1 at Leetown, received its first treatment with nigrosine May 3, before the new shoots had time to get started.

Our experiments and experience later showed that weeds in some manner absorbed the dye or at least caused it to disappear at a rate proportional to the quantity of weeds present.

From experience in killing weeds with sodium arsenite, I believe that Dr. Levardsen has misinterpreted the cause of the low oxygen in Pond No. 8 at Hastings, Michigan. Apparently he attributed the low oxygen to the presence of nigrosine itself, whereas I believe low oxygen conditions were being brought about by the destruction and decomposition of the plants he was trying to control.

At this stage, if carefully watched and if fresh water is available, lowered oxygen assists in getting rid of the weeds. When oxygen is low but not critically low in a pond, the fish (smallmouth bass, at least) will come to the surface, from which they are readily startled by a passer-by; but when critical oxygen conditions develop, they go to the shore. However, if treatment is early enough in the season, the oxygen problem should be trivial, for it can become critical only when a great mass of vegetation is present.

I have already discussed this with my friend Dr. Levardsen, who was kind enough to let me read his Michigan State College thesis on his weed control experiments; but our discussion of these points followed the mailing of his article to you.

Sincerely yours,

Eugene W. Surber
Aquatic Biologist

Muskellunge: a basis for argument among anglers, story-tellers, and orthographers.

A SPACED-DISC, SELF-CLEANING FISH SCREEN

Kenneth R. John
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CIVILIZED MAN had scarcely become interested in fishery management when he realized the need for screens to prevent fish losses. Unfortunately, the solution to the problem has not been simple.

Stationary screens are rendered useless by the debris which they accumulate, thus requiring that personnel be available constantly to clean them. This requirement is met more or less conveniently at stations housing permanent personnel, but it has been impractical to install such screens in remote locations. To solve the problem, various types of self-cleaning screens have been developed. Leitritz, in his review of the screening program in California (1952), discusses a variety of designs that have been tested. In his exposition, Leitritz recognizes the more or less limited applications of the designs described. It is apparent that they are not satisfactory unless attended more or less frequently. There is no gain in constructing an expensive mechanical screen if it fails to operate without surveillance. The cost can be justified only if the screen meets the operating standards required of it.

I was first confronted with the problem while developing some plans to investigate the survivability of hatchery-reared trout in Wyoming streams. The plans required a well-controlled experimental stream, divisible into sections that could be made fish-tight. As it was impossible to reside permanently at the location, there was need for a screen that would operate effectively though unattended for long intervals. The design offered here, though not fully tested, seems to satisfy this requirement.

In the description, no specific dimensions will be given, as these depend on a number of factors, among them being the flow of water through the screen and the size of the fish to be retained.

The screen is fundamentally a series of circular discs mounted concentrically on an axle. Washers alternating with the discs keep them uniformly spaced. Figure 1 illustrates the screen assembled for operation. No source of power is shown in the diagram. In operation, the cylinder is mounted in a runway and rotated in the direction indicated. Debris is carried over the top of the screen and removed on the downstream side by the water flowing through.

Short teeth are fixed into the margins of a few discs. There is enough horizontal space between teeth to allow fish to fall free should they be elevated on the teeth. The assembly is rendered fish-tight by a stationary guard at the bottom and a hinged guard above. Water shields, mounted on the axle next to the side of the runway, deflect water from the bearings. The bearings are further protected by sealed housings. The downstream end of the runway terminates just below the axle, except for the two sides which are extended to encase the side discs.

The drawings in figure 2 suggest a means of locking the assembly to the axle to prevent slippage. The notches in the discs and washers are aligned with the groove in the axle. A rectangular metal pin, inserted in the slot thus formed, locks the assembly to the axle.

To be effective, the teeth must lie in straight lines on the assembled screen.

To accomplish this, it is necessary that they be mounted on a disc, as indicated in figure 2, using the notch as a reference. The angle of the leading edge of the teeth will depend, of course, on the number of teeth used on a disc. I obtained satisfactory results with cylindrical teeth, but a more sturdy arrangement is advisable if the screen is expected to handle bulky pieces of drift. A pattern for stronger teeth is shown by the enlarged inset in figure 2. Whatever the choice, the leading edge of each tooth should be on a line described by extending the radius, and it should be smooth and straight for the best performance.

The thickness of the discs should be minimized, the objective being to build a satisfactory screen of least weight and dimensions for a given installation. However, the discs must be sufficiently rigid to resist distortion under the weight of individual items of drift. Consequently, the minimum satisfactory thickness is dependent on the diameter of the discs and their material composition.

The transfer of debris over the screen is enhanced by roughening the edges of the discs. Deeply notched discs would excel in this function but would complicate the construction of the entire apparatus. It would be difficult to make such a screen fish-tight. Moderately roughened discs and a few teeth will clear the debris.

The effectiveness of the screen depends on regularity in the spacing between the discs. It is essential that the discs and washers be made of material that is uniform in thickness and not subject to warping. The thickness of the washers, of course, depends on the size of fish to be retained. However, the washers serve also to maintain a uniform spacing between the discs. Effectiveness of the washers in this capacity is directly proportional to their diameter, but the ill effect of large diameters in hindering the flow of water through the screen compels the builder to adjust the scale of all parts to obtain--for the least cost--a maximum flow of water through the screen.

The need for constant spacing calls for a means of compressing the assemblage from both ends, a feat which is readily accomplished in various ways. Figure 3 illustrates one possibility: a stop washer is welded to the axle on one side of the screen, and pressure is applied on the other end with a lock nut.

The screen is made figh-tight by means of a stationary lower guard and a hinged upper guard. The upper guard, illustrated in figure 1, consists of a lightweight plate that is free to swing about an axle mounted across the top of the runway. The sides of the plate rest on stops which allow a minimum clearance between the teeth and the lower margin of the plate. If the screen is not equipped with teeth, the edge of the plate can rest nearer. The plate lies on a plane at an angle of about 30^{o} with the surface of the water.

The lower fish guard, though serving primarily to prohibit the passage of fish, is designed also to prevent fouling of the teeth, a condition which would stop the screen. Figure 4 shows the pattern of the lower guard. A groove is provided for each disc. Relatively shallow grooves are satisfactory, though they are proportionately deeper for the toothed discs. The edges of all the discs project a short distance below the upper surface of the guard. If a stick fell across the grooves, the advancing teeth would force it ahead and the plane of the lower guard would force it below the groove, thus allowing the teeth to pass through.

The lower guard projects a few inches above the bottom of the runway to protect the upstream side of the screen from heavy objects, such as rocks, which might be rolled downstream. The downstream edge of the lower guard lies directly below the axle.

The two ends of the screen are encased in the sides of the runway, as shown in figures 3 and 4. This eliminates undesirable stationary sides and makes it easy to effect fish-tightness. The side casings are thick enough to house the lock nut on one side and the stop washer on the other. In the drawing, the median surfaces of the two end discs are not flush with the inside walls of the runway. Instead, about one-half of the thickness of these discs lies

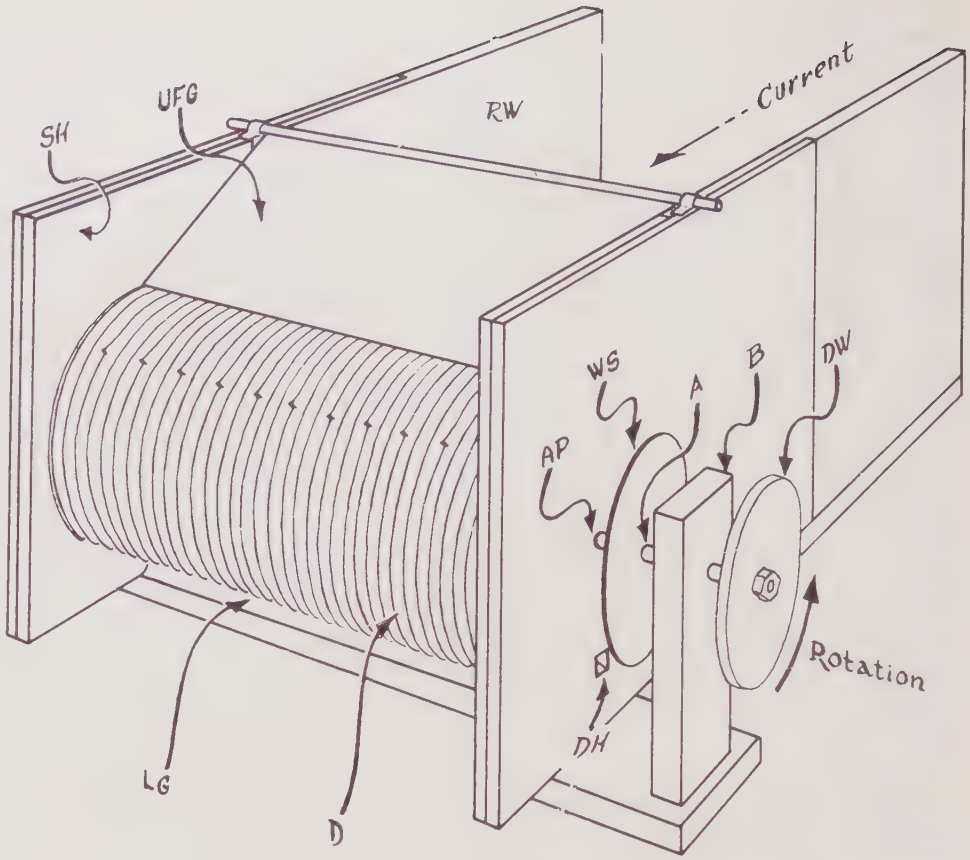


FIGURE 1.--Assembled screen: A--axle; AP--axle port; B--bearing; D--disc; DH--drain from housing; DW--drive wheel; LG--lower fish guard; RW--runway; SH--side housing; UFG--upper fish guard; WS--water shield to protect bearing.

(Illustrations courtesy of the author.)

within the runway, the other half of each being encased by the sides. Whereas this arrangement requires that the two side discs be thicker than the others, these discs can be somewhat thinner if the plan provides that the median surfaces be flush with the inner walls of the runway. No preference is stated for one or the other method, as they have not been compared in operation.

Small drains, indicated in figures 1, 3, and 4, lead from the bottom of the housings in order to prevent accumulations of silt. The drains may remove water faster than it enters the housings if the encasements closely circumscribe the discs. A close fit can be secured by having the opposing surfaces of discs and casings uniformly circular. The axle ports should be no larger than necessary to prevent friction, thereby minimizing the flow of water against the bearing shields.

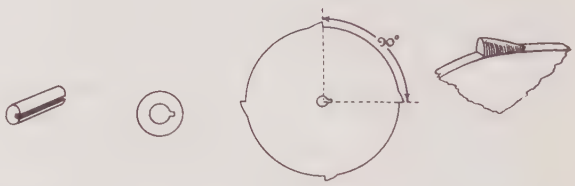
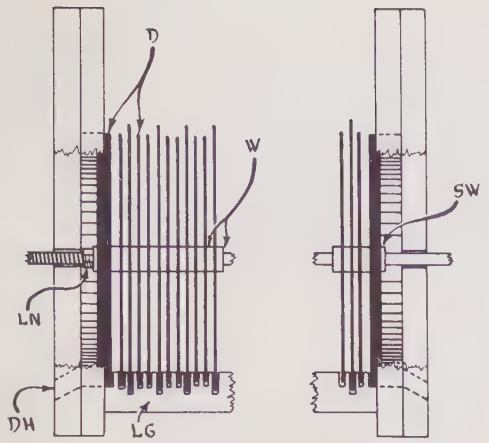
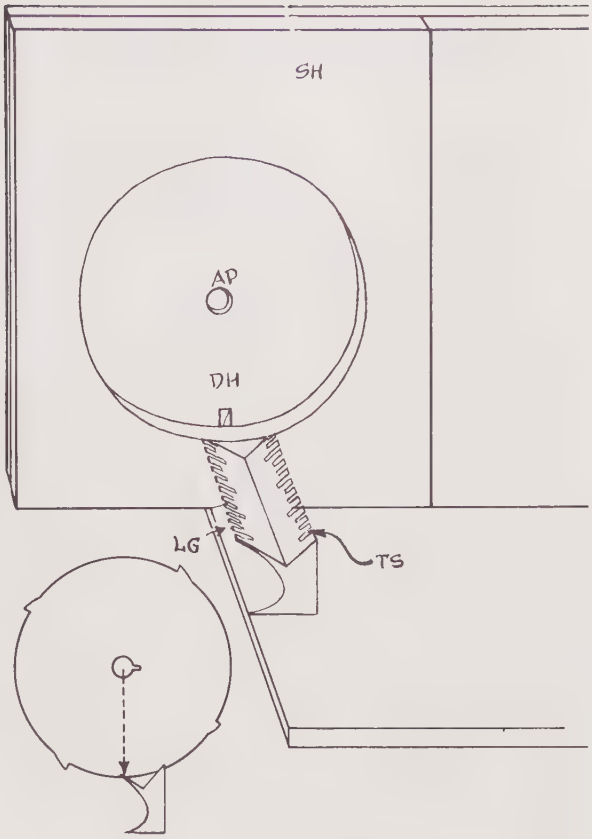


FIGURE 2.--From left to right, section of axle, washer, disc, and enlarged view of tooth on disc. Note that the leading edges of teeth lie along extended radii. (Drawings are not scaled.)

It is difficult to propose an exact design for the screen and runway without considering specific conditions. The foregoing description pertains to a screen for use under the most hazardous circumstances. In practice, some features here offered could be eliminated or modified to give the most satisfactory operation.



(Above)
FIGURE 3.--View of screen, without upper fish guard. D--discs; DH--drain from housing; LG--lower fish guard; LN--lock nut; SW--stop washer; W--washers. Shaded areas (horizontal lines) show the interiors of the side housings.



(Right)
FIGURE 4.--The runway, with the near side and screen removed. (The lower drawing shows how the discs mesh with the lower fish guard, the vertical arrow showing that the downstream edge of the lower fish guard is directly below the axle.) AP--axle port; DH--drain from housing; LG--lower fish guard; TS--slot for toothed disc.

Consideration must be given to the velocity of the water entering the screen, the speeds attainable by different sizes of fish, and related problems. The kind of debris or refuse carried in the water will determine the utility of teeth and the design of the lower fish guard. The silt content of the water and the immediate profile of the water course will influence the construction of the side encasements, drains, and runway.

Installing a screen durable enough to handle any sort of debris might be considered, but it would seem more practical to provide protection for a less sturdy screen. The weight of a screen built to withstand the passage of heavy driftwood would be prohibitive. Better results could be obtained by the judicious placement of a guard upstream to filter out the more cumbersome materials. This is mandatory, of course, if a water wheel is to supply power.

During the summer of 1953, the model shown in figure 5 was tested for short periods. Discarded phonograph records served satisfactorily as discs, though they were somewhat warped. The discs were 10 inches in diameter and about 1/16 inch thick. Cylindrical teeth, four to a disc, were set into the margin of every sixth record. The teeth jutted 1/2 inch beyond the edge of the disc. Wooden washers, 1 inch in diameter and 1/16 inch thick, made a fairly uniform spacing between discs. Lock nuts were applied to both ends of the axle, thus firmly compressing the assembly to avoid undue irregularities

in spacing. The runway was built to fit closely around the screen. The bottom was provided with grooves for the teeth. Strips of tin fitted into notches on either side of the runway were bearing surfaces for the screen. The water wheel shown supplied power. Bearing surfaces for the water wheel were wood against wood. The apparatus featured a high level of friction, but enough power to rotate the screen was supplied by reducing the speed from wheel to screen. Power was transferred through some rather crude belt pulleys; the belt was fashioned from a piece of chalk line.

The model was tested twice, each test lasting about an hour. It was installed in a rapid of a small stream where the water flow could be regulated. The first trials were made with a water level three-fourths the height of the discs. In later trials the water levels were lower, being reduced to one-fourth the height of the discs. Representative debris fed into the screen included dried leaves, green leaves, twigs, small branches, grass, moss, rounded sticks, involuted rhododendron leaves, and sticks three to four times as long as the screen's width.

Water depths exceeding half the height of the discs gave the most efficient operation; the three-quarter depth was most satisfactory. At water levels less than half the height of the discs, the screen did not carry rounded sticks over smoothly. This greater effectiveness at higher levels suggests the value of using the maximum depth that still prevents escape of fish. If a constant head of water is assured, there may be no need for teeth, the upper fish guard being put near enough to the top of the screen to prevent the escape of fish.

In its early stages, there seemed to be an obvious weakness in the design. It was not hard to imagine long strands of flimsy debris gathering on the axle or, specifically, on washers between the discs. The possibilities of such fouling have not been exhaustively studied, but particular attention was given this problem during the tests. The total mass of individual strands was carried over the top. Slender pieces seldom went between the discs to any extent; none became entangled on the axle.

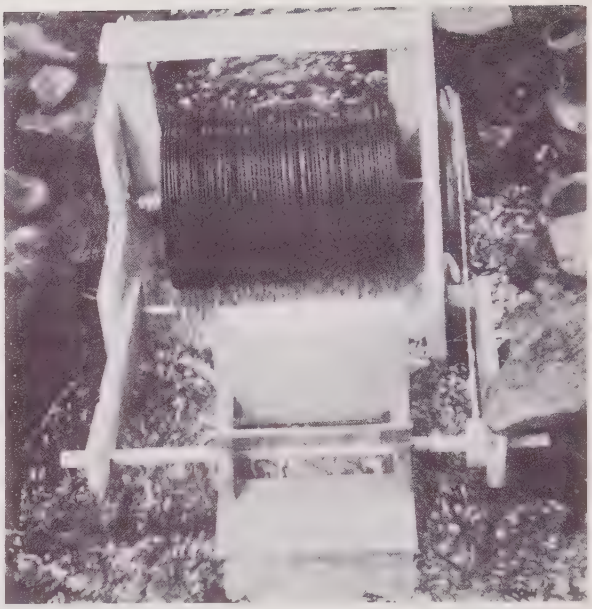


FIGURE 5.--The model in operation, viewed from downstream.

From these observations, I proposed the design described earlier in this paper. The crucial test of long, continuous operation under various circumstances has been undertaken by the fisheries division of the Wyoming Game and Fish Commission.

Advantages of the design can be summarized briefly. The screen has no moving parts exposed to water. It has no openings or perforations that can engage a stick and stop the machinery. A stick could become lodged between two discs, but the screen would continue to rotate. The screen's width can easily be altered by adding or subtracting discs if the installation is planned to allow such changes. The screen can be wholly disassembled for transport--a most desirable feature in some locations--and, by changing the thickness of washers, can be modified to retain different sizes of fish.

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METHOD OF PRODUCING PLASTIC IMPRESSIONS OF FISH SCALES WITHOUT USING HEAT

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THE WIDESPREAD USE of cellulose acetate impressions of fish scales for age and growth studies has led to the development of at least two satisfactory methods of making these impressions. One method employs an arbor press and sufficient heat to cause the plastic to flow. This results in what might be considered a mold or cast of the sculptured surface of the scale. Greenbank and O'Donnell (1950), and Butler and Smith (1953), among others, have described the structure and operation of arbor presses that have proved satisfactory. A second method of making scale impressions in plastic involves the use of a roller press similar to that described by Arnold (1951). The purpose of this discussion is to elaborate on the use of the roller press in scale-impression work and to describe some of the refinements developed in the Ann Arbor, Michigan, laboratory of the Great Lakes Fishery Investigations (U. S. Department of the Interior, Fish and Wildlife Service).

In our experimental work with the roller press, we sought to obtain a light impression in which the finest features of the scale, including the thin outer margin, were replicated. We are confident of having produced an impression which casts a projected image with features as fine and accurate as those from the scale itself and, in some instances, with less objectionable light refraction. Repeated comparisons of impressions with the actual scales have revealed no differences in measurements of importance in age and growth studies.

The method described by Arnold (1951) for making impressions of haddock scales was not completely satisfactory when used on scales from many Great Lakes fishes, particularly the thick, deeply sculptured scales of yellow perch, walleye, sheepshead, and white bass. Impressions made of these scales with a roller press and warmed plastic, as described by Arnold, are often dark and the scale markings coarse. It is difficult to obtain complete impressions from scales that have deep radial grooves in the anterior field. Further, in making impressions from these thicker scales, a slight flowage of warmed plastic away from the roller causes the last half of the scale to be impressed more deeply than the first half. This flowage may result in a distorted replication of the scale, as the plastic may tend to assume its original shape. Experimental work that led to the elimination of these undesirable features stressed two primary objectives: (1) the elimination of heat, and (2) a reduction of the pressure needed to obtain a complete impression.

At room temperature (70° to 90° F.), cellulose acetate slides measuring 1 inch by 3 inches were not distorted or permanently compressed when passed through a roller press under light pressure. But, as the pressure was increased, a point was reached above which the slide was permanently compressed. This pressure level has been termed the "crushing point" and has been set arbitrarily as the pressure at which the plastic remains compressed more than 0.0001 inch after it has

passed between the rollers. For convenience, the measure of pressure may be expressed as the distance between the rollers in relation to the thickness of the plastic strip. The crushing point of cellulose acetate was similar for products of several manufacturers.

In exploring the characteristics of the crushing point of 1- by 3-inch cellulose acetate slides, we noted that much greater compression and distortion resulted from a slight increase in pressure above the crushing point produced with small rollers than occurred when a similar increase was made in pressure above the crushing point produced with large rollers. Given the same spacing between rollers, the area of pressure application is smaller between small rollers than between large rollers because of differences in circumferential curvature. A greater pressure on a given area is exerted by the small rollers and, consequently, greater compression in the plastic strip results. The larger area of pressure between larger rollers reduces the pressure applied on a given area and therefore reduces the compression in the strip. The shallower impression made with large rollers, though perfectly reproducing characteristics of the scale, results in less light refraction.

As these results indicated that large rollers were more desirable in attaining our objective, subsequent studies were made with a press having rollers 3 inches in diameter. The crushing points of cellulose acetate, plotted as plastic thickness against opening between rollers, demonstrate a straight-line relationship (figure 1). The formula used to determine the opening between rollers 3 inches in diameter that will exert a pressure at the crushing point of cellulose acetate is as follows:

$$P = (0.9156\ T) - 0.00258,$$

where **P** is the opening between rollers and **T** is the thickness of the plastic.

Once the crushing point of a standard plastic strip is known, any hard object placed on the strip and passed through the roller press (which is set at the crushing point) will create an area of pressure in excess of the crushing point and imprint

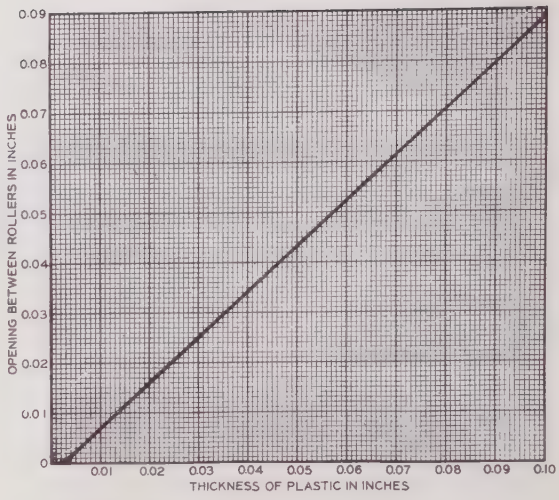

FIGURE 1.--The crushing points of cellulose acetate, plotted as plastic thickness against opening between rollers.

its sculpturing or other markings in the plastic strip. The markings impressed on the plastic strip must also conform, in depth, to the thickness irregularities of the object, because permanent compression increases as the pressure above the crushing point increases.

A roller press found satisfactory for making scale impressions is shown in figure 2. This press has rollers 3 inches in diameter. The opening between rollers is controlled by adjusting posts above the bearings on each end of the top roller. Circular scales on adjusting posts are marked with 0.001-inch graduations. A reduction-gear handcrank allows an operator to turn plastic through the rollers with relative ease. This press was fabricated at the machine shop of the University of Michigan.

Cellulose acetate strips 0.020 inch thick have been found satisfactory for all but very thick scales. At no time has it been necessary to use plastic thicker than 0.040 inch in our work. It is necessary to have plastic of uniform thickness if a number of scales are to be processed with the press at one setting. The maximum variation that we can use--and still obtain

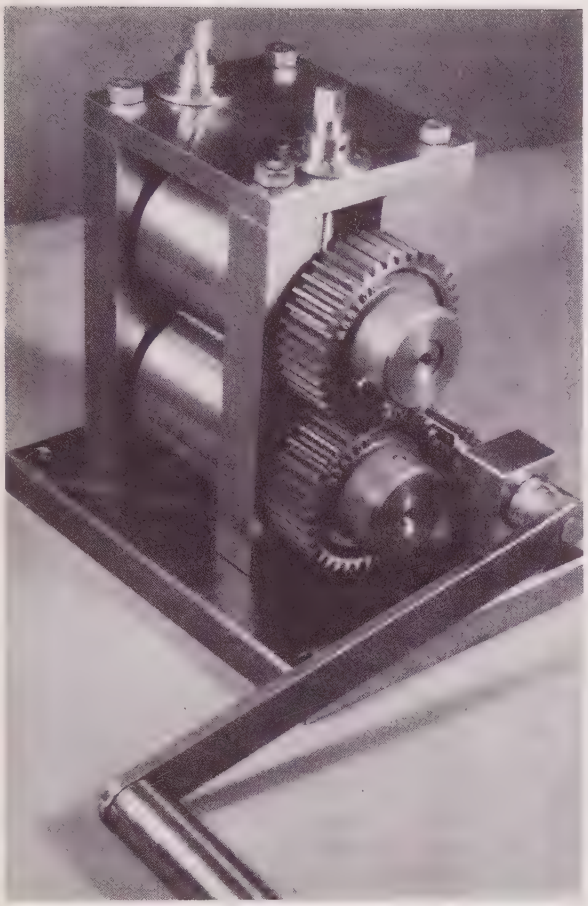

FIGURE 2.--The roller press. (For details of construction, write to: Chief, Great Lakes Fishery Investigation, 1220 E. Washington Street, Ann Arbor, Michigan.)

good impressions without changing the opening between rollers--is 0.001 inch. If a plastic sheet is not of uniform thickness, strips cut from the sheet must be measured with a micrometer and sorted into groups of uniform thickness. This sorting is rather a hindrance, but slides can be sorted at a rate of 300 to 400 an hour if the worker uses a small ratchet micrometer mounted on a stand so that it does not require handling during the operation.

Scales are mounted by setting the opening between rollers at the crushing point for the thickness of plastic being used. A few scales are placed--sculptured side down--on the plastic slide, which is then passed through the roller. We have never found it necessary to clean scales before mounting them; however, better impressions result if care is taken to scrape the slime from the fish before removing the scale sample. Scales that have been collected shortly before being mounted should be dried first in a dessicator for the best results. Wet scales are soft and often result in weak and incomplete impressions.

Although the plastic impressions made by the method just described are completely satisfactory, there are certain advantages in using two plastic slides with the scales placed between them. Both slides take some of the pressure that is caused by the scale, and a much shallower and lighter impression of the scale sculpture is obtained. It is difficult to obtain complete impressions of scales that have deep radial grooves when such scales are to be mounted on a single plastic slide; but when these scales are mounted between two slides, the deeper portions of the grooves impress perfectly. Other advantages to the use of two slides might be mentioned here: the scales are held firmly in place as the slides are fed into the rollers, and the scales do not stick to the rollers and thus necessitate frequent cleaning. The slide opposite the sculptured surface of the scales can be used repeatedly.

Satisfactory impressions have been made on film strips 0.002 to 0.004 inch thick by providing enough plastic backing material to take up most of the added pressure.

Completed mounts are always kept in the envelopes from which the scales were taken. This practice eliminates the possibility of error when the original data are transferred to the slide; it also eliminates the possibility of having a mount or set of mounts become disassociated from the respective collection information.

A permanent, fast-drying ink that can be used for marking or numbering plastic slides can be made by concentrating 50 milliliters of any good fountain-pen ink to

10 milliliters by evaporation, and adding 10 milliliters of acetone and 20 milliliters of glacial acetic acid. This ink is used with a fine-point dip pen. It will not rub or wash off the plastic slide.

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BASS SCALES MOUNTED ON TAPE

Recently a project in Maine required the reading of 750 smallmouth black bass (Micropterus dolomieu) scales. Speed in completing the readings was of paramount importance, but it was necessary also that the scales be preserved a short time for rechecking and for body-length, scale-length back-calculations.

John E. Watson, Department of Inland Fisheries and Game, Orono, Maine, has submitted the following description of the method used to mount these scales:

1. The dry scales from one fish were laid side by side, about 1/4 inch apart, on a microscope slide. The scales were laid sculptured side downward, the posterior edge pointing upward, so that the scales would appear right-side-up through the projector lens.

2. One strip of clear cellulose (Scotch) tape was applied across the face of the slide so that the scales were taped directly to the glass. The tape was cut about an inch beyond the right-hand edge of the slide. The overlap was bent back upon itself to form a tab.

3. When the reading was completed, and while the tape was still affixed to the slide, the number of the fish and its age were written with an ordinary fountain pen in a clear spot kept for that purpose on the tape at the left side of the slide. Unusually good specimens were encircled with pen and ink to facilitate rechecking.

4. The tape was then grasped by the tab and peeled cleanly from the slide. With the scales still neatly in place, the tape was applied to a sheet of good bond paper for storage. The 750 scales were thus stored on 13 sheets of 8-1/2- by 11-inch paper.

This procedure worked well with the scales of smallmouth black bass that had as many as seven winter marks. Scales of more than seven annuli generally had to be moistened with a few drops of detergent and pressed between two slides whose end margins were then taped together.

The method apparently has been found satisfactory also for white perch (Morone americana) scales, but it is considered inferior to the "water" method for the scales of trout and small salmon.

"This method is only as permanent as the tape itself," warns Mr. Watson. "It is essential that the tape be apposed to the smooth surface (usually the concavity in a dry specimen) of the scale. Moreover, the tape must be peeled slowly and carefully from the paper when a re-reading is desired. If the operator desires to remove certain scales from the tape, he may do so by wetting the scale with a few drops of toluene; the adhesive material of Scotch tape is soluble in that liquid."

MALACHITE GREEN OXALATE USED TO CONTROL FUNGUS ON YELLOW PIKEPERCH EGGS IN JAR HATCHERY OPERATIONS

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AT THE STATE FISH HATCHERY at Put-in-Bay, Ohio, fungus has long been a major problem, increasing the work load of hatchery personnel during the incubation period of yellow pikeperch (Stizostedion v. vitreum) eggs.

With the rise of water temperatures, fungus[1] invariably begins to appear on the dead eggs that form a collar floating on top of the living eggs in the battery jars. If left unattended, enough fungus gathers on the eggs to cause them to float over the jar tops, into the battery troughs, and thence to the fry holding tanks. In these tanks the eggs plug the screens and cause undue disorder to the operation. It has been the practice, therefore, to maintain a constant siphonage of the fungus-coated eggs at the top of the jars. When temperatures are above normal, however, it is difficult to keep these floating eggs under control even with adequate labor.

This experiment is not an attempt to determine which eggs become coated with fungus. It is, however, an attempt to control the fungus that gathers on the eggs--dead, unfertile, or living.

Hatchery

The Put-in-Bay hatchery contains 9 batteries of bell jars arranged 6 tiers in height. Each battery contains 288 jars, with a normal capacity of 10,080 quarts of yellow pikeperch eggs, and has a volume of 50 gallons of water per minute passing through it. During April and May 1953, approximately 500 million eggs (4-1/2 batteries) were processed at the hatchery.

Procedure

Upon arrival at the hatchery, the green eggs were water-hardened, set up in jars, and placed on the batteries.

From previous observations,[2] it was decided to use 6 grams of malachite green as the basic amount per treatment of each battery. Each 2 grams of malachite green was thoroughly mixed with 1 quart of water. Three quarts of this mixture was poured evenly along the top trough for a single treatment of one battery.

Table 1 contains information about each battery that was used in the experiment. Table 2 is the record of treatment with malachite green.

Notes

Battery No. 1. --No fungus was present prior to the first treatment with malachite green, and none appeared at any time during the incubation of eggs in this battery. No siphoning was required.

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[1] Although unidentified, this fungus is probably Saprolegnia sp., possibly S. ferox.

[2] Observations made by Harold Wascko, aquarium curator, Toledo Zoo, Toledo, Ohio. Wascko observed that this amount was non-lethal in his jar hatchery under similar conditions.

TABLE 1.--Hatchery records for yellow pikeperch, 1953

Battery number	Date	Weather	Water temperature °F.	Green eggs (quarts) Received	Eyed	Percentage eyed eggs	Percentage of eyed eggs
	April						
	6	Fair	41	280	144.5	51.6	
I	7	Fair	41	67	28.0	41.7	48.3
	8	Fair	43	494	215.0	43.5	
	9	Fair	44	43	21.5	50.0	
	10	Storm	45	5	2.0	40.0	
II	11	Fair	43	211	68.0	32.2	27.7
	12	Fair	44	290	51.0	17.5	
	13	Fair	43	39	17.0	43.5	
	14	Fair	43	336	93.5	27.7	
	15	Fair	45	135	39.0	28.8	
III	16	Storm	43	-	-	-	30.4
	17	Fair	43	246	74.5	30.2	
	18	Fair	42	639	223.0	34.8	
	19	Snow	42	54	24.0	44.4	
IV	20	Storm	42	39	12.0	30.7	35.6
	21	Fair	41	381	104.0	27.2	
	22	Fair	42	21	6.0	28.5	
	23	Fair	44	13	6.0	46.1	
	24	Fair	44	22	7.0	31.8	
	25	Fair	45	21	0	0	
	26	Fair	45	5	1.0	20.0	
V	27	Fair	44	21	9.0	42.8	23.2
	28	Fair	44	9	4.0	44.4	
	29	Fair	45	-	-	-	
	30	Fair	45	6	0	0	
	May						
	1	Fair	47	6	2.0	33.3	
Totals and percentage				3,365	1,152.0	34.2	

Battery No. 2.--Virtually all dead eggs eventually became coated with fungus, floated to the jar tops, and required constant siphoning. As the eggs that are received earliest usually have the highest percentage of hatch, the percentage of hatch of this battery would ordinarily be expected to be higher. The relatively poor showing of this battery is attributable in part to the poor condition of spawn that arrived on April 12, i.e., 5 eyed quarts from 126 quarts of green eggs received. Otherwise the battery was considered normal and was treated as such.

Battery No. 3.--Treatment was undertaken immediately after this battery was set up, because by that time fungus had already begun to appear. The amount of fungus visible was enough to float to the top of the jars a small collar of dead eggs, which were siphoned off at will. After this one treatment with malachite green, the amount of fungus remained the same for 5 to 6 days, after which a gradual increase appeared. At no time, however, did the increased amount of fungus equal that in any of the untreated batteries. This battery did not need or receive the constant attention required by untreated batteries.

Battery No. 4.--The battery was untreated. There was a normal amount of fungus on the dead eggs, which required constant attention.

After fungus had formed on the dead eggs, two jars were picked at random and treated with malachite green in the same proportion that was used for one application in batteries 1 and 3. The malachite green did not tend to adhere to the fungus, which was unaffected by the treatment.

Battery No. 5.--These were the last eggs to arrive at the hatchery; so only half of the battery was utilized. As is normally the situation, these last eggs produced the lowest percentage of hatch. The battery was untreated. Fungus developed rapidly and required constant attention.

Four jars were picked at random and treated with malachite green in the same way as were the test jars in battery 4. In these jars the fungus was well advanced prior to treatment, and this application had no noticeable effect on the fungus.

TABLE 2.--Notations of malachite green application

Battery number	Set-up dates (April)	Dates of treatment (April)	Relative amount of fungus observed	Percentage of eyed eggs
I	6 to 8	10, 15, and 21	None present	48.3
II	8 to 12	Untreated	Normal amount	27.7
III	13 to 18	15	Some, but retarded	30.4
IV	18 to 21	Untreated	Normal amount	35.6
V	21 to 30	Untreated	Normal amount	23.2

Lethal Effects

To check the lethal effects on living eggs, a typical jar was chosen from each of batteries 1 and 2. Each jar was treated separately with 2 grams of malachite green mixed in 1 quart of water.

The color washed out of these two jars in 48 hours and had no apparent ill effect on the living eggs. In a normal battery treatment the color washed through in 8 to 10 hours; in the treatment of random-chosen jars from batteries 4 and 5, the passage of the color took 12 hours.

These two jars were in different stages of incubation but were treated on the same date. No fungus was visible at any time during the incubation period. The dead eggs milled around the living eggs after treatment and did not float. The living eggs appeared to hatch normally.

General

For additional information, it will be desirable to have more rigid control of the time and number of treatments. In this instance, the dates of arrival and the amount of spawn the hatchery received were not known beforehand.

The experiment has shown that, under running-water conditions, highly concentrated solutions of malachite green are not harmful to living eggs. It has been shown that one application at an early stage may temporarily retard the growth of fungus, and that two or more applications, if made at an early stage, may inhibit the growth of fungus which ordinarily is visible to the naked eye.

When two or more applications were used, the decomposition of dead eggs resulted in obnoxious odors. These odors are such that they might cause undesirable working conditions for some people.

Another consideration is that when there is no collar of fungus-coated eggs, there is no separation of living and dead eggs. It is thus difficult to obtain an accurate percentage of hatch.[3/]

Perhaps the most important fact revealed by this experiment is that malachite green may be used to the exclusion of all visible fungus without apparent harm to the living eggs.

Further experimentation is planned with treatments of lower concentrations

3/ This is desirable because Ohio pays commercial fishermen for spawn according to the number of eyed eggs in the hatchery.

of malachite green and with treatments immediately after the first siphoning has been necessary.

Conclusions

1. Repeated use (three applications) of malachite green oxalate on yellow pike-perch eggs in jar hatchery operations at Put-in-Bay--

A. Appears to rid eggs of all visible fungus.

B. Apparently is not harmful to living eggs.

C. Causes obnoxious odors.

D. Makes it difficult to ascertain the percentage of hatch.

2. One application of malachite green oxalate at an early stage (as soon as fungus appears) will retard but not prevent the growth of fungus.

Acknowledgments

Much of this work was accomplished through the efforts of hatchery personnel: Messrs. Miller, Borman, Kindt, Dodge, and Morrison.

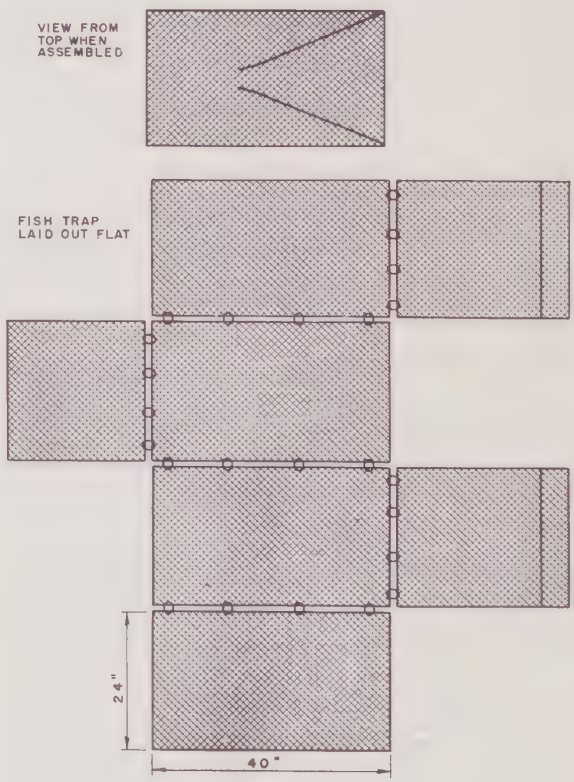
A COLLAPSIBLE WIRE FISH TRAP

The wire fish trap recommended by Dr. K. D. Carlander of Iowa State College needs little maintenance and can readily be folded into a small area for storage or transport.

Galvanized hardware cloth, 1/2-inch mesh, is put on frames made of No. 8 galvanized wire. Top, bottom, and two side frames are identical, 40 by 24 inches--though, if 24-inch hardware cloth is used, the frames should be a little less than 24 inches to allow for overlap of the wire. Each frame is formed of a single piece of wire, the ends overlapped and soldered. (As some traps have needed more soldering after 2 years' use, welding would be better.) The back is 24 by 24 inches. The wings that make the throat are on 24- by 24-inch frames, but each has an additional 6 inches of wire mesh on one side. This loose wire can be bent to form the throat opening, a slit 2 to 4 inches wide from top to bottom of the trap.

The pieces of the trap are fastened together with metal rings (hog nose rings) on the edges indicated in the drawing. The rings allow the trap to be folded compactly or set up for use in a few minutes. When the trap is being set, the other edges are tied together at three or four points with twine--or with hog rings or short wires if the trap is to be set for several weeks. The throat wings can be held in place by tying each to the bottom piece at one point and to the top at two points.

Fish can be removed from the lifted trap by pressing down on the bottom and slipping them under the throat.



CONTROL OF A BRANCHED ALGA, *PITHOPHORA*, IN FARM FISHPONDS

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IN THE SOUTHEAST, within the last 5 years, several hundred farm fishponds have become infested with a branched form of filamentous algae that is called Pithophora. Most forms of filamentous algae occurring in ponds in the Southeast normally grow in cold water and die during the summer; this branched form, however, grows best during the warmer months. Once Pithophora has become established, it forms a heavy blanket of floating alga over much of the pond surface and thus renders a pond unfit for fishing (figure 1). In experiments at Auburn this alga has reduced fish production by as much as 50 percent by competing with the phytoplankton for the plant nutrients during the summer growing period. Pithophora also tends to produce overcrowded bluegill populations by preventing adequate predation by bass.

Pithophora has a characteristic cluster-like form of growth, as shown in figure 2. As the filaments of this alga are rather large, these clusters look like discolored masses of hair or cotton floating on the water. When handled, this alga feels coarse, much like wet cotton. There is no slick or slimy feeling such as is characteristic of most of the single-filament forms of alga.

As already mentioned, the filaments of Pithophora are branched (figure 3). This branching is visible to the naked eye if strands of the alga are laid on a light surface such as a thumb nail. One may note, also, when examining a sample of this alga, the presence of dark spots scattered along the filaments (figure 4). These spots are the akinetes or "seed" from which new filaments or branches sprout. In a young, rapidly growing culture of this alga, these "seed" spots are rare; but as the branches become older, possibly every other segment may contain one of these akinetes. At present it is not known how long these akinetes will remain alive on the pond bottom.

Pithophora may be on a pond bottom in isolated clusters for weeks or months before it is detected or becomes a menace. It usually makes its first appearance as a few isolated clusters on the edge of the pond; then the plankton algae decrease in abundance, causing the water to become clear; and finally the clusters of Pithophora appear in abundance all over the pond. This condition may develop within 2 to 3 weeks. It is during this period of development that the control measures should be applied.

The most satisfactory and economical control measure for Pithophora at present is to treat the entire pond with dehydroabietylamine acetate. At a concentration of 0.7 p.p.m., this material is toxic to bluegills, goldfish, and young largemouth black bass. Therefore, it would be wise to avoid treating a pond in a 4-week period after bass spawning, and to avoid treating pond areas where bream beds are located.

Tests indicate that the branched alga may be killed by a concentration of less than 0.5 p.p.m. of this acetate in the pond

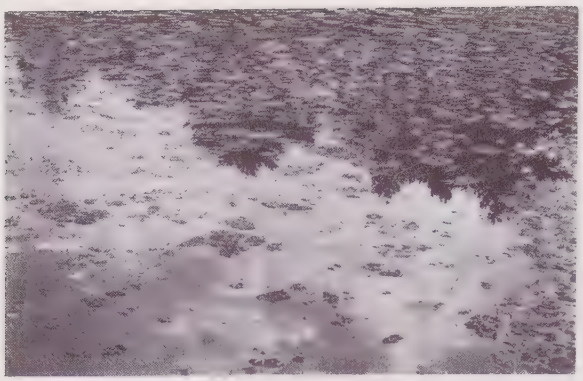

FIGURE 1.--The surface of this small experimental pond is covered with a heavy growth of the alga called Pithophora.

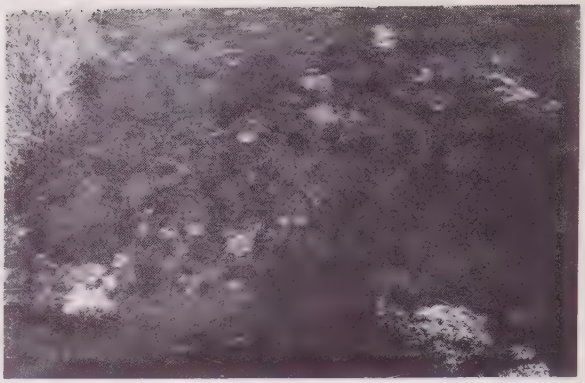

FIGURE 2.--A close-up of the edge of a pond infested with Pithophora. Note the heavy, clumplike growth covering the pond bottom.

when the water temperature is above 70° F. At present there is insufficient evidence to determine the effects of this material on the akinetes of Pithophora. Thus, it is necessary to make repeated applications of dehydroabietylamine acetate as new growths of Pithophora appear. This practice, if followed, will keep the Pithophora under control and should eventually eliminate it from the pond.

Dehydroabietylamine acetate is manufactured by the Naval Stores Division of the Hercules Powder Company (Wilmington, Delaware) and is available under the trade name of Hercules Algicide D. It is available as a 70-percent paste (Hercules Algicide D-70) and as a 50-percent solution (Hercules Algicide D-50S).

Treatment Procedures

Three methods of applying Hercules Algicide D have proved satisfactory in ponds infested with Pithophora. One method is to apply Hercules Algicide D as a spray solution. Another method is to drag burlap bags containing Hercules Algicide D paste over the pond surface. A third and simple method is to place Hercules Algicide D paste in floating boxes that have burlap bottoms.

Hercules Algicide D is applied at the rate of 2.5 to 3.0 pounds of active ingredient per surface acre per application. When more than one application is necessary to control the growth of Pithophora in a pond, additional applications (at the same rate per acre) are made at weekly intervals or whenever regrowth is sufficient to warrant another treatment.

Regardless of the method of application, the amount of material applied must not exceed the recommended amounts--or death of fish may result. Thus the pond owner should first determine the surface area of the pond as accurately as possible and then weigh accurately the amount of material required to treat this given area.

Spraying method.--To obtain a good coverage of the floating masses of algae in a reasonable length of time, some type of power spray that is capable of developing 100 to 150 pounds of pressure must be available. Also, the liquid form, Hercules Algicide D-50S, should be used. This liquid form is applied at the rate of 5 to 6 pounds per surface acre per application.

The required amount of the algicide is placed in the spray tank and mixed with an equal amount of water before being applied as a spray. Normally good coverage is obtained when the spray is applied as a coarse mist at a pressure of about 100 pounds. When spraying this algicide, the operators should wear goggles because the mist from this spray solution is irritating to the eyes.

Dragging method.--This method is recommended for large ponds when rapid

FIGURE 3.--A strand of rapidly growing Pithophora that shows the prolific branching of the filaments. Note the absence of akinetes in the filaments.

FIGURE 4.--A strand of older Pithophora that shows the abundant production of akinetes (the dark, bulblike spots that appear on the filaments).

treatment is desired, and for ponds having irregular shorelines. In this method the Hercules Algicide D-70 is applied at a rate of 3 to 4 pounds per surface acre per application.

The required amount of 70-percent paste is placed in loosely woven burlap bags. For best results not more than 25 pounds of the paste should be placed in one bag.

These instructions should be closely followed to prevent killing fish with Hercules Algicide D-70:

The burlap bag containing the algicide paste should be tied to the front end of a boat powered with an outboard motor. The bag should be tied so that it will drag loosely in the water when the boat is in motion. Do not drop the bag into the water until the motor is started and the boat is in motion. If the boat is stopped while the material is being put out, immediately remove the bag from the water. Leaving the bag of algicide in the water while the boat is stopped will release such a concentration of material that it will be toxic to the fish.

Tow the algicide in a spiral pattern: for the first line of algicide, run the boat as close to the pond edge as possible; then make smaller circuits (20 to 30 feet apart) until most of the pond area is covered. If the locations of spawning beds in a pond are known, take precautions to stay a considerable distance from these areas when applying this material.

Float method.--This method is recommended for all ponds having deep edges that are free from marginal weed growth. It is especially advantageous for use in the smaller farm fishponds. The Hercules Algicide D-70 paste, recommended for this method, is applied at the rate of 3 to 4 pounds per surface acre per application.

The slides for the floating box are made from 1- by 10- or 12-inch boards. The boards are cut into 18- or 24-inch lengths, and these are nailed together to form the walls for the float. The bottom is then covered with two thicknesses of loosely woven burlap bag material. (Tightly woven burlap has not proved satisfactory, as the algicide cannot diffuse through this bagging at a sufficiently rapid rate.) A piece of hardware cloth (4 mesh per inch) is stapled outside the burlap to strengthen the bottom.

The finished floats are placed in the pond at points 10 to 20 feet from the bank so that water currents can spread the dissolved algicide over the pond. Usually stakes are driven in the pond bottom and the floats are attached to these stakes with a string some 5 feet long (figure 5). The required amount of paste is then placed in the floats. If the wooden sides do not have

FIGURE 5.-- A wooden float box filled with Algicide D paste and staked in the edge of a pond. Observe the whitish drift of Algicide D in the water on the left side of the float.

(Illustrations courtesy of the author)

sufficient buoyancy to float the paste, bottles or sealed cans may be tied to the floats to deep the top of sides above the water.

The number of floats required to treat a pond adequately depends on its shape as well as its size. Normally, the average 2- to 3-acre pond requires two floats for adequate coverage. These floats may be moved about over the pond from time to time to give better distribution of the algicide. Treatment of larger ponds requires a float for each 3 to 4 acres.

Used in the float method, Hercules Algicide D-70 dissolves and is distributed over the entire pond within 36 hours. Previous experiments with nigrosine in this same type of float showed that in this period of time a complete and uniform coloring of the pond surface was obtained.

Weed Control and Fertilization

To obtain the best control of Pithophora with Hercules Algicide D, all vegetation growing above the surface of the water, especially along the pond edge, must be removed. This can be done by cutting the weeds or spraying them with a solution of 2,4-D plus diesel fuel.

Field experiments at Auburn have shown that Hercules Algicide D is not toxic to the phytoplankton when applied at the rates recommended here. Rather, when the algicide is applied and the Pithophora starts to die, the pond water turns green. Thus ponds infested with Pithophora should receive regular applications of the recommended kinds and amounts of inorganic fertilizer during and after treatment with Algicide D to stimulate this phytoplankton growth. To hasten the decay of the algae killed by the treatment, the pond may be fertilized with 15 pounds of ammonium nitrate or 20 pounds of ammonium sulphate per acre. This nitrogen material should be applied about 4 days after the application of algicide. The reason for this delay is that the nitrate or sulphate radical in the fertilizer can react with dehydroabietylamine acetate and replace the acetate, making the material ineffective as a killing agent for Pithophora.

Toxicity of Dehydroabietylamine Acetate to Livestock

At present, there are no available laboratory data regarding the toxicity of Hercules Algicide D to cattle, hogs, or sheep. However, in the summer of 1953 cows obtained their only drinking water from certain ponds treated with this material and apparently suffered no ill effects.

SUSPECTED ULCER DISEASE IN THE GOLDEN SHINER, *NOTEMIGONUS CRYSOLEUCAS* (MITCHILL)

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A REARING POND for golden shiners, Notemigonus crysoleucas (Mitchill), was inspected after a report of a fish die-off had been received. The pond was about half an acre in area. It received some barnyard drainage, but the water was free of heavy algal growth. The temperature of the water was 15° C., and the dissolved oxygen content was 11 p.p.m. Many diseased fish were seen swimming slowly and erratically near the surface of the water, and the shoreline was littered with hundreds of dead golden shiners.

The diseased fish exhibited respiratory distress, and examination showed that all of them had unilateral ulcerations of the gill lamellae. Most of these fish had one or more small white tufts on the skin along the sides of the body. Large reddened areas from which the skin had been sloughed were seen on some of the fish. The soft tissue between the rays of the caudal fins was partly eroded on some fish. Gross inspection of the internal organs revealed no apparent abnormality, with the exception of the fact that in a few fish the kidneys were softened and hemorrhagic in appearance.

Twenty of the living but diseased fish were transferred to the laboratory and put in an aquarium. All died within a few days. Stained preparations of material from external ulcers on the fish revealed gram-negative rods. Most of the rods occurred individually and were 5 microns or more in length, but a few of the organisms were very short and occurred in short chains as well as singly.

Samples of blood and material from the external ulcers were injected into nutrient broth tubes and streaked upon nutrient agar plates. Discrete colonies of various types of organisms appeared on the plates, and fermentation occurred in the tubes. Most of the organisms were tentatively identified as being of the genus Pseudomonas; others were classified as being of the genera Proteus and Sarcina.

Healthy fish that had not been exposed to the original disease were inoculated with the various organisms appearing on the plates. A few of the fish that had been inoculated with the Pseudomonas organisms developed large ulcers at the inoculation site and died. However, these fish died without showing any of the typical lesions seen in the original epizootic.

A supply of healthy shiners was then obtained and distributed among three aquaria. One of these aquaria had previously contained the 20 diseased fish. The shiners in the two clean aquaria remained in good condition, whereas those that were placed in the infected aquarium contracted the disease within 3 to 7 days and died. Shiners inoculated with material from these fish developed the typical symptoms and died.

Upon consideration of Snieszko's paper (1952) describing ulcer disease in brook

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A cooperative study sponsored by the Division of Fisheries, Illinois Department of Conservation, and Southern Illinois University.

trout, an investigation was begun along the lines suggested by that worker. Microscopic examination of the material from the tufts on the bodies of the fish showed that the tufts were composed of peculiar strands of epithelial cells, which Fish (1934) considered characteristic of ulcer disease.

In order to extend the diagnosis, a bacteriological medium was made of the composition suggested by Snieszko. Also, a fish-extract supplement was prepared by grinding healthy golden shiners, centrifuging, and running the supernatant liquid through a sterilizing Seitz filter. Six plates were prepared with basal medium plus the fish extract: three of these plates were streaked with blood inoculum and three with ulcer inoculum. In addition, six plates were prepared with only the basal medium: three of these plates were streaked with blood and three with ulcer inoculum.

After a 2-day incubation period at 20° C., numerous colonies of various kinds of organisms appeared on all media. On two of the six plates which contained the supplemented medium, fine lines of transparent pin-point colonies were seen. These plates were in the set of three which had been inoculated by streaking with aortic blood from three infected fish.

Microscopic inspection of the colonies showed very small gram-negative rods, so short as to appear coccoid. These organisms were nonmotile in hanging-drop preparations and were identified as belonging to the genus Hemophilus. However, identification was based only on morphological characteristics and Snieszko's presumptive test (Snieszko 1952).

Ten healthy fish were inoculated from the Hemophilus colonies by scratching the inner side of the operculum with the inoculating needle. Nine of these fish developed symptoms similar to those of the ulcer disease in trout described by Snieszko. One fish recovered after it had developed the typical symptoms of the disease. This specimen exhibited resistance to reinfection.

All attempts to reisolate the suspect organism from the fish which had been infected from the laboratory medium failed. However, in reisolation attempts, the fish-extract supplement was not the same as that used in the original isolation. As fresh golden shiners were not readily available, extracts used in the reisolation attempts were made from frozen fish that had been held for some time. An extract made from a fresh largemouth black bass, Micropterus salmoides (Lacepede), was also tried but was a failure. The failure to reproduce growth of the fastidious Hemophilus organisms might be attributed to the use of unsatisfactory supplementary fish extract.

In conclusion, even though the study is not so complete as might be desired, it is safe to say that there occurred in a pond population of golden shiners a major die-off due to a bacterial disease. The bacterium was probably of the genus Hemophilus.

Acknowledgments

The writers wish to thank Dr. Dan O. McCleary for his advice on bacteriological procedures used in this investigation. Mr. Sam Parr cooperated on behalf of the Division of Fisheries.

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1934. Ulcer disease of trout. Trans. Am. Fish. Soc. 64: 252-258.

In the 1952-53 season, 17,652,478 anglers' licenses were purchased for $35,602,903.

THE NORTHERN PIKE HATCH AT THE CLEAR LAKE (IOWA) HATCHERY

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THE FISHERY MANAGEMENT section of the Iowa Conservation Commission has hatched northern pike (Esox lucius) at the Spirit Lake hatchery each year since 1947, but the 1953 season marked the first year for this work at the Clear Lake station.

For several years prior to 1953, the adult population of northern pike in Clear Lake (area, 3,643 acres; maximum depth, 20 feet) was very low. During the spring of 1951, a few adult northern pike were stocked in Ventura Marsh, a 630-acre marsh that drained into Clear Lake and was separated from the lake by a road grade. During the spawning run these adults were collected in a combination carp-trap and water-control structure located on the marsh side of a bridge over the outlet of the marsh. Seine hauls and other observations late in summer indicated that there was a large number of fingerling northern pike in the marsh. Late in the fall of 1951, the stop logs of the control structure were removed and the northern pike were allowed to migrate to the lake. No count was made of the returning northern pike. This procedure was repeated in 1952, when more than 5,000 northern pike fingerlings were recorded as they moved to the lake. These fingerlings were the result of a relatively poor run of adults in the spring of 1952. Early in the 1953 spawning run, a large number of small northern pike appeared in the trap.

In spite of the questionable spawning ability of the small northern pike, it was decided to transfer 100 females and 200 males to the marsh, the remainder of the catch to be held in the trap for later use in the hatchery.

Collection of Northern Pike in the Carp Trap

The first northern pike appeared in the trap March 15, while the lake was still covered with ice. On March 19, 24 females and 8 males were placed in the marsh. On March 21, when about one-half of the lake was covered with ice, there were approximately 600 females and 200 males in the trap. This reversal of the expected sex ratios might be explained by the fact that these fish were 2 years old and therefore were just maturing. Possibly in this situation the females matured earlier than the males. At this time the remainder of the 300 fish were transferred to the marsh.

Northern pike held in the trap were checked each day to find ripe females, but no signs of egg flow were noted until March 30. On this date 200 females and 40 males were removed to the hatchery, where 12 females were stripped. Thereafter the trap was seined every other day to collect ripe fish for hatchery use. By April 4, the male-female ratio was estimated to be about even and no additional fish were entering the trap. In spite of cool water temperatures (less than 42° F. during the entire period), the females continued to ripen until April 13. On April 14, all northern pike in the trap were removed to the lake.

Age and Size of Northern Pike

Scale samples from a random group of 29 fish revealed that the group included only 1 fish (a 4-pound female) that had more than 2 years' growth; thus, if this sample was unbiased, better than 96 percent of the run was made up of fish with only 2 years' growth. General observations made during routine handling seemed to indicate an even higher percentage of fish in the 1951 year class. Length and weight data for these 2-year-old fish appear in table 1.

TABLE 1.--Average lengths and weights of 28 two-year-old northern pike taken from Clear Lake carp trap, 1953

Sex	Number of fish	Total lengths (inches)		Weight (pounds)	
		Average	Range	Average	Range
Male	9	17.9	16.2 - 19.5	1.5	1.1 - 1.9
Female	19	20.3	18.5 - 22.2	2.4	1.9 - 3.2

Hatchery Procedure and Production

Spawn-taking.--In the hatchery the northern pike were checked each day by slight pressure on the abdomen. Only females from which eggs flowed freely were used.

The eggs from two to three females were stripped into a 1-quart pan that contained just enough water to cover the bottom; these were followed by sperm from one to several males. Eggs and sperm were mixed by gently rotating and tilting the pan. This mixture was then carefully poured into a larger container that was about half filled with water. After a hardening period of about three-quarters of an hour, the water was decanted and the eggs were transferred to a standard hatching jar and placed on the battery. The final stages of the hardening took place while the eggs were in the hatching jar. No starch, muck, or clay water was used to separate the eggs. Very little trouble was experienced here in the task of keeping the eggs "rolling."

Production.--The first females were stripped on March 30 and the last females on April 13. In this period 540 females produced 81 quarts of eggs (table 2). Eggs from these fish were of uniform size but rather small for the northern pike, as they averaged 75,000 per liquid quart.

Fifty-two percent (42.2 quarts) of these northern pike eggs survived to the eyed or hatching stage, thus producing 3,165,000 fry.

Table 2 indicates that the average female produced approximately 11,000 eggs. An actual count of the eggs that were stripped from a female weighing 2.5 pounds totaled 22,745.

TABLE 2.--Number of male and female northern pike stripped, total quarts of eggs obtained, quantity and number of eggs per female for each day of operation at Clear Lake hatchery, 1953

Date	Number of females	Number of males	Total quarts of eggs	Quarts per female	Number of eggs per female [1]
March 30	12	4	3.0	0.25	18,750
31	72	49	14.0	0.19	14,250
April 1	9	9	1.5	0.17	12,750
2	63	58	8.0	0.13	9,750
3	83	121	14.5	0.17	12,750
4	22	31	3.0	0.14	10,500
6	72	76	12.0	0.17	12,750
8	[2] 77	68	10.0	0.13	9,750
9	[3] 79	83	9.0	0.11	8,250
11	35	37	4.0	0.11	8,250
13	16	17	2.0	0.13	9,750
Totals and/or averages	540	553	81.0	0.15	11,250

[1] Based on 75,000 eggs per quart.
[2] 12 not very good. [3] A few not good.

DIVIDENDS FROM RESEARCH

THE PISGAH SYSTEM

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"The Pisgah System" is a now-famous instance of the improvement that research and management have made in angling for trout. The system has evolved since 1937 from a program of stream studies having as its goal: "The most trout fishing for the most trout fishermen, and an equal opportunity for every angler." 1/

The trout management area in the Pisgah National Forest in western North Carolina contains approximately 150 miles of streams. The U. S. Forest Service and the U. S. Fish and Wildlife Service cooperated in intensive research on these waters from 1937 through 1941. The successful research and management plan which resulted is presently supervised by the same Federal agencies and the North Carolina Wildlife Resources Commission.

The Pisgah system has a number of characteristics which distinguish it from the various programs used in other areas with heavy fishing pressures. The supply of stream-native trout is supplemented with a carefully determined number of legal-sized hatchery fish to meet the fishing demand. Thorough studies have been made of the carrying capacities of all streams and of the survival of fall- and spring-stocked fingerling and legal-sized trout, in order to assure the economical use of hatchery trout, secure the greatest returns to anglers, and minimize the dangers of overstocking. Emphasis is placed on the full utilization of the food supply at all seasons. Stocking of legal-sized trout begins in the spring, coincident with the seasonal abundance of natural food for both native and planted fish.

Every advantage that has been determined by research is granted to the wild trout populations. These advantages include relief from undue competition with stocked fish; better habitat, food supply, and spawning conditions as the result of stream improvements; and reduction of silting and predation (poaching) as the result of improved forest practices and control. The expected increase of native and carry-over trout has occurred; creel returns in 1952 indicated an increase of more than 100 percent.

Pisgah devotees boast, "Every fishing day an opening day." Studies of the fish populations, carrying capacities of the streams, and creel records enable the managers of the Pisgah to regulate the number of fishing days per season that each stream can provide. The quota of days for a stream is divided to allow a period of rest between open days, as both wild trout and stocked trout tend to become overly wary under intensive angling. Study has also shown when, during the season, a particular stream will yield the best fishing. The demonstrated result is a more equitable distribution of trout among the anglers.

The success of the Pisgah system is measured in fisherman-days, each representing an angler who purchases for $1 a permit to fish for a day. In 1937, there were 1,091 fisherman-days and a catch of 6,322 fish was recorded. By 1946, after 10 years of operation, the number of fisherman-days had increased to 8,202

See footnotes at end of article.

and the size of the catch to 35,038 trout.[1] In 1952, 14,459 anglers caught 56,184 fish.[2] The objective, to make the Pisgah one of the finest trout-fishing areas by means of a nearly self-supporting program of management based upon research, has been attained.

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[1] Chamberlain, T. K., and W. W. Huber, 1947: Ten years of trout stream management on the Pisgah. Prog. Fish-Cult. 9 (4): 185-191.

[2] Ratledge, H. M., 1953: Fish management investigations of trout streams. Quart. Prog. Rept., Fish Div., N. Car. Wildl. Res. Com. 2: 19-36.

A STUDY OF THE RELATIVE MERITS OF NATURAL AND ARTIFICIAL PROPAGATION OF SOCKEYE SALMON IN BRITISH COLUMBIA

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The artificial propagation or hatchery production of sockeye salmon (Oncorhynchus nerka) became, in the early 1900's, one of the principal means by which the Federal Department of Fisheries of Canada endeavored to maintain and--if possible--increase the stocks of this species, which was then being actively exploited by a rapidly increasing commercial fishery.

The first Canadian salmon hatchery was established on the Fraser River in 1894. Thereafter the number increased until, in the period 1921-32, there were 10 hatcheries operating in British Columbia, collecting annually an average of approximately 85 million eggs.

Yet for many years there had been a growing feeling that, in spite of the rather extensive operation of the hatcheries, no beneficial results were accruing. In the words of the British Columbia Fisheries Commission of 1922: "It was made quite evident to us that the old hatchery methods were of little commercial value ... Consequently, we urge that before the service is extended, some definite experimental tests should be carried on for a series of years. We make the condition, however, that the operations be carried on and observations made directly under competent scientific supervision."

In 1925 a scientific study of the relative efficiencies of natural and artificial propagation of sockeye salmon was commenced by the (then) Biological Board of Canada at Cultus Lake, a tributary of the lower Fraser River, where a natural run of sockeye occurred and where a hatchery had been in operation for some years. Three tests each of (1) natural propagation, (2) artificial propagation with liberation of fry, and (3) artificial propagation with planting of "eyed" eggs were planned, the efficiency to be based on the number of seaward-migrating smolts produced from the potential egg capacity of the adult females arriving at the counting weir below the lakes.

By 1934, the following percentages of efficiency had been obtained:

Natural propagation-----	1.13, 1.05, 3.16, or an average of 1.78
Fry liberation----------	3.93, 2.38, 1.71, or an average of 2.67
Egg planting----------	0.95, 3.55, or an average of 2.25

So little difference between the methods had been demonstrated that it was concluded that "in an area, such as Cultus Lake, where a natural run of sockeye occurs with a reasonable expectancy of successful spawning, artificial propagation, for purposes of continuing the run to that area, is unnecessary and, if producing any additional results over natural spawning, these would not appear to be in any way commensurate with the cost."

Additional information was presented to show that (a) the average annual egg collections at all hatcheries (77.3 million) probably represented about 3 percent of the egg capacity of the spawning runs, and (b) that heavy mortality occurs shortly after the fry are released into the lake. Among marked sockeye released from

rearing ponds into the lake, mortality amounted to 67 percent after 7 months' lake residence and to 78 percent after 9 months' lake residence.

As a result of the conclusions that were reached by the Biological Board of Canada from these findings, and presented to the Department of Fisheries, all Pacific salmon hatcheries in Canada were closed in 1935. Subsequent study of the populations of sockeye returning to areas where hatcheries had previously operated has not shown any adverse effect from the cessation of hatchery operation.

INVESTIGATION AND MANAGEMENT OF THE COLUMBIA RIVER SPRING CHINOOK SALMON

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The spring runs of chinook salmon to the Columbia River have long been known and valued for the high quality of their flesh. Those fish entering the river from February to early August are grouped here as spring chinooks to distinguish them from later arrivals of lower fat content and somewhat different life history. The earlier runs were the main support of the commercial fishery for this species during the latter part of the 19th century and the first decades of the present century. With the passing of time, however, it has been quite evident that the spring chinook runs to the Columbia River were declining.

As might be expected, a variety of reasons was offered in explanation of the observed decrease in runs. The major causes advanced were the troll fishery, the intense river fishery, and watershed changes resulting from development of the various water uses accompanying civilization. Certainly the continued expansion in the troll catch over the past four decades has had a part in this decline; similarly, it is obvious that total destruction of large areas of the original spawning grounds in the Columbia River basin has had marked effect on the abundance of chinook salmon. These two factors have been investigated to some degree, and certain corrective steps have been--and will continue to be--taken. For brevity, however, this discussion is limited to the effect of the third factor, the commercial river fishery. Willis H. Rich, in a study in which the river catch was compared with known escapements from counts made by the U. S. Army Corps of Engineers at Bonneville Dam, first established the actual rate of fishing within the river, thereby largely removing this factor from a speculative position. Dr. Rich's studies showed that the landings represented about 80 to 85 percent of the early running fish, in addition to the ocean catch. This catch was large enough to make it evident that the river fishery was in all probability partly responsible for the observed decline.

The States of Washington and Oregon, which jointly administer this fishery, took corrective action in 1943 by providing an additional closed season--the length of which has ranged from 20 to 31 days--beginning in late May. Subsequently a 2-week period in July was also closed. These closures were chosen on the basis of studies designed to find the length of time needed for effective protection and to improve the escapement of specific runs.

The results of the measures have been evident in improved escapements of spring chinook salmon to the spawning grounds. The counts of these fish passing Bonneville Dam have risen steadily since 1943: they ranged from 65,000 to 100,000 between 1939 and 1943 but have been much greater in recent years. The count in 1952 was 200,000. By July 31, 1953, about 228,000 spring chinook had been recorded, all-time high since completion of the dam in 1938.

Owing to scarcity of fish and curtailed fishing, the catch had dropped to 1,700,000 pounds by 1946. Since then, though restrictions have not been relaxed, landings have generally increased. The 1952 catch was the highest in more than a decade, exceeding substantially the catches made just before increased regulation. A good catch was realized in 1953 also.

REVIEW

CULTURE AND DISEASES OF GAME FISHES

H. S. Davis
University of California Press, Berkeley & Los Angeles, 1953, x + 332 pp., illus. $5.

As an all-inclusive or perfect book has never been published, a reviewer should evaluate the book on the basis of the success that the author has had in reaching the goal he set for himself. The purpose and scope of Dr. Davis' book are best expressed in his own words:

> I have made no attempt to discuss in detail all phases of fish culture, ... my purpose has been to give a comprehensive account of the methods commonly employed and which, during the years, have proved most successful. ...
>
> The section on fish parasites and diseases was prepared for the use of fish culturists and others with no special training in this field. ... Many diseases known to affect fish in this country have been omitted, either because available information regarding them is too fragmentary to be of value or they are so rare that their inclusion would serve no useful purpose.

The first part of this book covers a number of topics, including a brief history of fish culture; the location and construction of hatcheries; and the propagation, care, food, and rearing of all species of trout, Pacific salmon, grayling, pikeperch, pike, and muskellunge. A chapter which is devoted to the construction and operation of ponds for warm-water fishes is followed by three chapters that provide fairly detailed information regarding the propagation of black basses and other centrarchids, channel catfish, minnows, and suckers. There is a chapter dealing with farm ponds and related problems--construction, stocking, and the maintenance of a balanced population. Chapters that deal with the raising and propagation of trout have been taken from the author's well-known publication entitled "Care and Diseases of Trout," which had two editions and several printings. It should be pointed out, however, that this text has been considerably expanded, revised, and brought up to date.

The second part of this book is devoted to the parasites and diseases of game fishes. This section, also an expanded and revised presentation of material that appeared in Dr. Davis' earlier publication entitled "Care and Diseases of Trout," is of unique value as being almost the only up-to-date discussion of these topics in English. The work of earlier writers on these topics is largely out of date, out of print, or perhaps--as is the difficulty with Lyman's manual on fish diseases--written in a language that is unfamiliar to most English readers.

A careful examination of this second section shows that the subject matter has been covered accurately and comprehensively. A highly critical reviewer would offer only very minor complaints, pointing out, for example, that Kamala might well have been given consideration in the discussion of control measures for endoparasitic worms, or that the toxicity of pyridylmercuric acetate technical to rainbow trout should have been mentioned, or

perhaps that one type of the disease called popeye here (pp. 287-288) has been named kidney disease since the preparation of this text. Inevitably, a few errors have been overlooked by both author and proof-reader: thus, on page 245, calomel or carbasone should have been recommended at the concentration of 0.2 percent, or 1 gram per pound, instead of 2 percent for the treatment of octomitiasis; and, on page 272, malachite green should have been recommended at a concentration of 1:15,000 instead of 1:1,500 for the control of Saprolegnia fungus. Several other errors that were noticed by this reviewer were of less significance and should be corrected in the second printing or edition of the book.

This reviewer feels that Dr. Davis' new book must be regarded as an important contribution to the modern literature on fish culture. Topics covered by this author in previous publications have been so extensively expanded and so thoroughly revised that the result is a completely new publication--one which may be strongly recommended to everybody who is interested in the production of fresh-water game fishes.

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SILICONE STOPCOCK GREASE AS PROTECTION FOR HANDS

Individuals who must spawn, fin-clip, tag, or otherwise handle fish are well acquainted with the discomfort experienced--and with the difficulty in maintaining the highest efficiency--when the hands must be exposed to cold water for extended periods.

Leon D. Johnson, aquatic biologist with the Wisconsin Conservation Department, stationed at Spooner, Wisconsin, recommends the use of silicone stopcock grease as protection for the hands:

"Several silicone salves have been tested, but the silicone stopcock grease was found most economical. One application will usually suffice for half a day, though it may wear off more quickly as a result of the handling of dip nets or other tools.

"Silicone stopcock grease provides better protection for the hands than vaseline or lanolin. It may be purchased from scientific supply houses for about $1.25 per 2-ounce tube."

SEINE FOR SMALL CHANNEL CATFISH

A special treatment of the seine has been reported very helpful in the handling of small channel catfish at the U. S. Fish-Cultural Station at Fort Worth, Texas.

The seine with which the fish are to be moved is first dipped into asphalt varnish that has been thinned slightly. When the varnish dries, it stiffens the fiber of the seine appreciably. This stiffened fiber offers much less opportunity for the hanging of the small channel catfish by their dorsal and pectoral spines.

K. W. Morrison, superintendent of the Fort Worth Station, reports that this technique permits more rapid handling of the small catfish and reduces mortality.

A tagged northern pike, recaptured twice more by biologists and finally by an angler, had grown 14.4 inches in the 1,729 days between his tagging and ultimate recovery.

CLEARING HOUSE

Use of fish products in blueback salmon diets.--G. I. Jones, M. E. Stansby, N. L. Karrick, William Clegg, George Pigott, R. E. Burrows, L. A. Robinson, D. D. Palmer, R. G. Landgraf, Jr., and D. T. Miyauchi.
Spec. Sci. Rept., Fish.
No. 106. 59 pp., illus.
Nov. 1953. (processed)

Experimental transportation of live shad past Susquehanna River dams.--C. H. Walburg.
Spec. Sci. Rept., Fish.
No. 114. 13 pp., illus.
Jan. 1954. (processed)
-- Fish and Wildlife Service
U. S. Department of the Interior
Interior Building
Washington 25, D. C.

The Black River studies.--J. L. Funk, E. M. Lowry, and M. H. Patriarche; R. G. Martin; R. S. Campbell and T. R. O'Connell, Jr.
136 pp., illus. $2.50.
Vol. XXVI, No. 2. 1953.
-- The University of Missouri Studies
Columbia, Missouri.

Homemade fishing: bass and trout waters you can build yourself.--V. E. Davison.
205 pp., illus. $4.50.
1953.
-- Stackpole Company
Harrisburg, Pennsylvania.

Analysis of factors affecting the production of chum salmon (Oncorhynchus keta) in Tillamook Bay.--K. A. Henry.
Contrib. No. 18.
37 pp., illus. Sept. 1953.
-- Fish Commission of Oregon
Portland, Oregon.

Biotic influences affecting population growth of planktonic algae.--T. R. Rice.
Fish. Bull. 87 (Fish. Bull., Fish and Wildlife Service 54: 227-245). 1954. 25¢.

Improving duck marshes by weed control.--A. C. Martin.
Circular 19. 49 pp., illus.
1953. 20¢.

Pacific salmon: hatchery propagation and its role in fishery management.--Wm. Hagen, Jr.
Circular 24. 56 pp., illus.
1953. 30¢.

Propagation and distribution of food fishes for the calendar years 1949-1950.--L. M. Duncan and O. L. Meehean.
Statistical Digest 28.
38 pp. 1953. 20¢.
-- Superintendent of Documents
Government Printing Office
Washington 25, D. C.

Intertidal invertebrates of the central California coast: S. F. Light's "Laboratory and field text in invertebrate zoology."--revision by R. I. Smith, F. A. Pitelka, D. P. Abbott, F. M. Weesner, and others.
vi, 446 pp., illus. $5.
1954.
-- University of California Press
Berkeley and Los Angeles
California.

The behavior and reproduction of salmonid fishes in a small coastal stream.--J. C. Briggs.
Fish. Bull. 94. 62 pp., illus.
1953.
-- California State Fisheries Laboratory
Terminal Island Station
San Pedro, California.

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